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NOT ONLY TIMBER

The potential for managing non-timber forest products in tropical production forests—a comprehensive literature review

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The potential for managing non-timber forest products in tropical production forests—a comprehensive literature review

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The International Tropical Timber Organization (ITTO) is an intergovernmental organization promoting the conservation and sustainable management, use and trade of tropical forest resources. Its members represent the bulk of the world's tropical forests and of the global tropical timber trade. ITTO develops internationally agreed policy documents to promote sustainable forest management and forest conservation and assists tropical member countries to adapt such policies to local circumstances and to implement them in the field through projects. In addition, ITTO collects, analyzes and disseminates data on the production and trade of tropical timber and funds projects and other actions aimed at developing sustainable forest industries at both the community and industrial scales. Since it became operational in 1987, ITTO has funded more than 1200 projects, pre-projects and activities valued at more than USD 430 million. All projects are funded by voluntary contributions, the major donors to date being the governments of Japan and the United States of America.

The Precious Forests Foundation—established in May 2018—is dedicated to improving the sustainable use and valorization of tropical forests, thus contributing to the lasting preservation of their ecosystem services for both local communities and the planet and to the responsible multiple use of their renewable wood and non-wood products. The foundation promotes and finances innovations based on applied research relevant to the practice of certified sustainable forest management. Its goal is to improve certified sustainable forest management through knowledge and innovative solutions so that it becomes a viable business model to protect forests and provide livelihoods to local communities and is attractive for (impact) investments. The Precious Forests Foundation is a non-profit, denominationally and politically neutral Swiss foundation, with its headquarters in Zürich.

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Front-cover photo: Harvesting wild cocoa in tropical Bolivia. © S. Opladen/Helvetas

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FOREWORD

There is a clear and urgent need to step up efforts to protect tropical forests. Large areas are still being lost, along with precious biodiversity, carbon, ecosystem services and community income. Although our attention is focused presently on containing the COVID-19 pandemic, the bigger challenge is climate change, with the loss of tropical forest responsible for about 10% of greenhouse-gas emissions globally. About 70% of all tropical forests lie outside protected areas and are subject to productive use, and it is essential that such forests are managed under legal, sustainable and verified forest management to ensure that their many values are maintained.

The Precious Forests Foundation commissioned the study presented here from the international forestry team at the School of Agricultural Forest and Food Sciences, Bern University of Applied Sciences. The aim was to explore possible additional income streams to strengthen the economic viability of sustainable forest management in permanent tropical production forests while protecting and maintaining the environmental attributes of forests in sustainable ways.

Tropical forests provide much more value, commercially and for communities, than just timber and wild meat. For centuries, forest-dependent peoples have known and used numerous edible nuts, fruits and other plant parts for food and medicine—what today we call non-timber forest products (NTFPs). New applications (e.g. for natural pharmaceuticals) of lesser-known NTFPs are being discovered every day. The first challenge, covered in this study, is to understand how these NTFPs can be grown and harvested in harmony as core elements of multiple-use management in tropical production forests while respecting traditional forest-community interests and rights. The second challenge, which will be covered in a follow-up study, is to identify tangible sustainable business development opportunities and hurdles.

ITTO has long supported the development of NTFPs as one means for generating sustainable income from tropical production forests, especially for local people. It has done this through many projects and studies in the three tropical regions and by convening an international conference on NTFPs in 2007, the outcomes of which were published in *Gifts from the Forest*.

The Precious Forests Foundation and ITTO are proud to present this report to encourage innovative and sustainable business development involving NTFPs that respects the essential attributes of tropical forests. Given the growing demands on tropical forests for the many goods and ecosystem services they provide, multiple-use management approaches are essential. We wish you an interesting and enjoyable read.

Ted van der Put
Chair, Precious Forests Foundation

Steven Johnson
Officer-in-charge, ITTO

June 2021

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Special thanks go to Dr Robert Nasi, a member of the board at the Precious Forests Foundation, for his encouragement for the study and to Robert Hunink at Precious Woods Ltd for reviewing the paper. The authors thank Jeanne Ehrensperger at the Precious Forests Foundation for coordinating the work between the foundation and ITTO, Ramon Carrillo at ITTO for his support in the preparation of the report, and Alastair Sarre for editing the document and his additional valuable inputs into its content.

Jürgen Blaser, Juliana Frizzo and Lindsey Norgrove

June 2021

ABBREVIATIONS AND ACRONYMS

BRL	Brazilian real
CIB	Congolaise Industrielle des Bois
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	centimetre(s)
dbh	diameter at breast height
EUR	euro(s)
FAO	Food and Agriculture Organization of the United Nations
FLEGT	Forest Law Enforcement, Governance and Trade
FMU	forest management unit
FSC	Forest Stewardship Council
g	gram
ha	hectare(s)
IDR	Indonesian rupiah(s)
INR	Indian rupee(s)
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
kg	kilogram(s)
LAK	Lao kip(s)
m	metre(s)
NTFP	non-timber forest product
NWFP	non-wood forest product
PFF	Precious Forest Foundation
PPP	purchasing power parity
PWA	Precious Woods Amazon, known also as Mil Madeiras in Brazil
SFM	sustainable forest management
USD	United States dollar(s)
XOF	CFA franc(s)

EXECUTIVE SUMMARY

Non-timber forest products (NTFPs) are goods originating in forest that are not directly related to timber production; the term encompasses any product harvested—formally or informally—in the forest other than timber. This literature review explores the case for multiple-use forest management in natural tropical production forests in which NTFPs help make the economic case for natural forests.

Multiple-use management in tropical production forests can have various forms, including the following:

- managing commercial timber species that also produce valuable NTFPs;
- managing species that produce timber and species that produce NTFPs in the same area;
- combining the harvest of commercial timber and palm species; and
- increasing NTFP production in timber production forests through enrichment planting.

Only a few examples exist of efforts to combine the management of timber and NTFPs within the same forest management unit under a multiple-use management approach. Thus, such integrated approaches to the sustainable management of natural tropical forests remain elusive.

Two important factors influencing the sustainability of NTFP harvesting are the plant component harvested and the life history of the species (including pattern of growth, reproduction and pollination). For long-lived perennials such as shrubs and trees, the extraction of reproductive parts—fruits, flowers and seeds—tends to have high potential for sustainable harvesting.

In broadening the scope of management in tropical production forests, in particular to manage for both timber and NTFPs in the same forest management unit, the following core elements need to be considered:

- the inclusion of both timber and NTFPs in forest inventories;
- the conceptualization of appropriate silvicultural and ecological management regimes;
- the evaluation of possible conflicts in the use of multipurpose tree species;
- the design of wildlife conservation strategies and regulated hunting approaches; and
- the development of tenure and access rights.

Multiple-use forest management in tropical production forests faces various economic, technical and administrative constraints. Although NTFPs are extremely important for local livelihoods throughout the tropics, and many NTFPs are traded in significant quantities at the local, national, regional and global scales, data on their long-term use and economic value remain scarce. Timber is still the only forest commodity with major lucrative markets; the tropical timber sector is based on a reliable body of technical knowledge and makes a significant contribution to the economies of many tropical countries.

The compatible management of timber and NTFPs is complex, multifactorial and context-dependent; it may be possible in some situations but difficult to achieve in others. Moreover, the management of NTFPs is often ad hoc, and little is known about their sustainability at the local scale.

Ideally, the process to develop multiple-use forest management approaches in tropical production forests should begin with land-use planning because it implies a thorough assessment of biophysical, social, regulatory and institutional aspects. Overall, two broad approaches could be taken:

1) Improve existing situations on a case-by-case basis, particularly where forest management is entrusted to long-term concession contracts (either community-based or private). Inventories, management planning, harvesting and marketing would address both timber and NTFPs within an overall concept of managing forests and their products and services sustainably.
2) Develop new management regimes that explicitly encourage the sustainable production of timber and NTFPs, and the delivery of ecosystem services, over long timeframes.

Managing tropical forests for multiple products, ecosystem services and stakeholders requires processes for negotiation and shared decision-making—going beyond discussion platforms and committees designed to bring together local users and forest concessionaires and forest industries, which are mandated by law in some tropical countries.

The report presents three examples of well-established NTFPs in humid tropical forests: Brazil nut; rattan; and rubber. For each, it examines the factors and strategies that have enabled the sustainable harvesting of the NTFP and are now supporting continued success and the challenges that have arisen in maintaining a sustainable NTFP management regime.

The report also describes six promising NTFPs that grow in tropical forests—two each from tropical Africa (allanblackia and African plum), Southeast Asia (agarwood and damar resin) and the Amazon (açaí and wild cocoa)—and for which the potential is yet to be fully realized. In some cases, the NTFP has largely been domesticated and enriched in forests or grown in agroforestry systems. Some NTFPs have natural or synthetic substitutes. In other cases, the NTFPs are unique, novel and have no comparable substitute. In all the case studies presented here, more information is needed on multiple-use forest management to produce timber and NTFPs while ensuring economic viability, social equity and forest conservation.

Combining the sustainable production of timber and NTFPs has various degrees of potential, depending on the context. Here, we use a 1–5 star rating system to estimate the potential of 28 individual NTFPs to yield positive economic, social and environmental outcomes.

The review shows that the compatible management of timber and NTFPs is inherently multifactorial and context-dependent. Compatibility is possible in some cases but might prove difficult to achieve in others, at least in the short run. There is, however, a lack of studies on integrated management approaches that effectively combine the production of timber and NTFPs; the concept, therefore, requires field-level implementation to explore its feasibility.

Governance issues, such as those related to land tenure, collective institutions, and the design of multistakeholder management models, must be addressed to enable multiple-use forest management in the tropics. Testing multiple-use management approaches in forests where governments have a direct supporting role could prove fruitful.

There are three (interrelated) ways to move forward on multiple-use forest management involving timber and NTFPs:

1) indirectly improving "passive" or "opportunistic" compatibility situations, for example by enforcing the mitigation of logging impacts on NTFP resources;
2) explicitly enhancing both timber and NTFP values, including through the concurrent management of locally important NTFPs; and
3) assessing the biophysical (forest), social, regulatory and institutional aspects of multiple-use forest management for timber and NTFPs with a view to minimizing trade-offs among stakeholders.

For many NTFPs, recent information on production volumes and prices is lacking, including for some major NTFPs. There is an urgent need, therefore, for market studies of the NTFPs presented here, and others, to assist efforts to encourage sustainable production and thereby better contribute to forest conservation and the livelihoods of forest-dependent people. A follow-up study, underway in 2021, aims to identify the tangible sustainable business development opportunities and hurdles (see www.precious-forests.foundation).

More research is needed to determine the economic case for multiple-use forests in diverse contexts. Nevertheless, integrating NTFP management in timber production forests could be a decisive step in the development of such management approaches, bearing in mind the imperative to use natural tropical forests wisely and sustainably or lose them forever.

1 THE CASE FOR MULTIPLE-USE MANAGEMENT FOR TIMBER AND NON-TIMBER PRODUCTS IN THE TROPICS

Timber is widely recognized as the main forest product and commodity. Since the development of the first scientific forest practices, all approaches to long-term forest management have focused on timber (and occasionally woodfuel). The concept of sustained timber yield implies that no more timber should be removed from a forest than will grow back in a given time; it gives no consideration to other forest products.

But a new term—"non-timber forest product" (NTFP)—emerged globally several decades ago for grouping forest products and commodities that are "not timber". Similar terms had been used previously, such as "minor forest products", "byproducts of forests", "other forest products", "secondary forest products" and "special forest products", but "NTFP" implied a new way of looking at these products.

What is an NTFP? According to De Beer and McDermott (1989), NTFPs comprise "all biological materials other than timber, which are extracted from forests for human use". Thus, NTFPs are goods originating in forests that are not directly related to timber production. The term encompasses any product harvested—formally or informally—in the forest other than timber (CIFOR 2008). It considers plant products such as resins, fruits and medicinal plants as well as animal products such as honey and wild meat (also known as bushmeat) (Belcher 2003). Augustino et al. (2011) defined NTFPs as including products used locally, regionally, nationally or internationally as food, cosmetics (oils), herbs, aromatic substances, fodder for domestic animals, medicines, firewood, construction material, ornamental plants, resin and colourants as well as animal products derived from collecting and hunting, the latter for food, medicines and trophies.

There has been discussion in the past on the inclusion or otherwise of woody materials such as woodfuel (encompassing firewood and charcoal) and small wood (e.g. for carving) in definitions of NTFPs. The Food and Agriculture Organization of the United Nations (FAO) uses the term non-wood forest products (NWFPs), which excludes such materials (Belcher 2003), and definitions of NTFPs, in contrast, generally include woodfuel and small wood. This document adopts the position that the same socioeconomic factors are often at play in the production, use and sale of woodfuel and small wood as those applying to NTFPs; thus, the term (and concept of) NTFP is used in this report.

The present study focuses on certain NTFPs that are or can potentially be valorized in the framework of sustainably managing natural tropical production forests. NTFPs (and ecosystem services—Box 1) are potentially valuable commodities and important elements of sustainable, multiple-use forest management that serves broader conservation and local development goals. The development of NTFPs has been advanced as a mechanism for adding value—in addition to timber—to the management of forest stands. If they are managed sustainably and actively to generate income, NTFPs can help offset the opportunity costs of retaining forest as forest rather than converting it to other, potentially more profitable land uses. The sustainable production of NTFPs, which might include management practices such as assisted natural regeneration, plant breeding and enrichment planting,[1] can support both local livelihoods and nature conservation (Uprety et al. 2016); therefore, it can be a valuable addition to the income generated by timber production.

In the rest of this chapter, we explore the case for multiple-use forest management in natural tropical production forests in which timber, NTFPs and ecosystem services all help make the economic case for natural forests. We look at the evidence, the challenges and the opportunities. Chapter 2 describes three well-established NTFPs, including their success factors, potential and challenges. Chapter 3 looks at six other NTFPs with considerable potential for increased production in natural forests. Chapter 4 tabulates key data for and descriptions of 24 NTFPs, and Chapter 5 draws conclusions on the potential of NTFPs in tropical production forests.

1 Enrichment planting is the planting of desired tree species for timber or NTFPs under the canopy of natural forests and woodlands with the objective of creating a managed forest dominated by desirable species in the long term.

Box 1: Forest products and services—two sides of the same coin

Forest products, also referred to as forest goods, comprise both timber and non-timber forest products. In addition to these, forests produce ecosystem services (also called environmental services)[2] such as the production of clean water, the conservation of soils and biodiversity, and carbon sequestration. Some forest services can potentially be valorized through payment schemes for ecosystem services, the aim of which is to incentivize forest owners and managers to manage their forest resources in ways that maintain the provision of such services. Payments for ecosystem services can be part of multiple-use strategies to generate a competitive income from forests, potentially combined with timber and non-timber forest products.

What we know about managing non-timber forest products in tropical forests

There is a vast literature on the management and potential of NTFPs in accessible forests, including wide-ranging studies by various international scientific and development organizations.

NTFP management is often considered an alternative to timber management, and the focus of many projects and studies has been at the scale of small forest management units (FMUs) managed by communities and producer associations. Many hundreds of NTFP species and their commercialization are described in the literature; most are only locally important, but some have significant national and international markets—gutta-percha and rattan, for example, have been traded internationally for more than 100 years, and others have been globally significant for at least 20 years. A well-documented case of a locally used NTFP that has become an internationally traded product is açaí, a product obtained from *Euterpe oleracea* (an Amazonian palm tree, which also produces palm hearts). The Brazilian American company Sambazon began exporting açaí pulp from the Brazilian Amazon in 2000 to produce lifestyle juices, smoothies and energy drinks (Prado 2012). Today, Sambazon is an established multi-million-dollar business, the products of which are distributed worldwide. Numerous globally established NTFPs have been domesticated, particularly through continuous breeding, and grown as agricultural crops. Many now common products such as avocado, banana, cocoa, coffee, durian, litchi, palm oil, papaya and rubber are among dozens of NTFPs that have been domesticated for more than 100 years. Many are produced today in traditional and systematic agroforestry systems, sometimes in combination with timber species—such as samba (*Triplochiton scleroxylon*) in West Africa and cedro (*Cedrela odorata*) in tropical America.

Although general information is available on the occurrence, collection, use and marketing of many NTFPs, research and experience is scarce on the management of lesser-known NTFPs in tropical production forests. A case in point is the Swiss–Brazilian, FSC-certified forest enterprise, Precious Woods Amazon (PWA), which manages nearly 0.5 million ha of natural forest in the Brazilian state of Amazonas, producing hardwood timber for export and the Brazilian market. On its land, which is 98% forested, the company combines timber production with the management of logging debris[3] to produce woodfuel. PWA also manages a small area of enrichment planting of Brazil nut (*Bertholletia excelsa*) and trials of enrichment planting involving other NTFPs. The concept of enrichment planting with NTFP species is relatively new (but see Box 2); PWA is working with local communities and enterprises to pave the way for multiple-use forest management.

ITTO co-organized a major international conference in Beijing, China, in 2007 to explore the sustainable development of NTFPs and forest ecosystem services. Among other things, the conference found that a lack of clear resource tenure, access and rights inhibits the development of small-scale and community-based forest enterprises, which are vital actors in NTFP value-adding and marketing (Box 3 presents more findings of the conference and other work on NTFPs undertaken by ITTO).

The commercialization and harvesting of NTFPs have been encouraged since the late 1980s as an alternative way to protect forests and biodiversity by generating incomes and subsistence for local people (Weinstein and Moegenburg 2004). It was assumed that, as markets grew for NTFPs, forests providing these products would gain in value and therefore be less prone to deforestation. Additionally, the trade in

2 For more information on ecosystem services, see www.itto.int/sustainable_forest_management/environmental_services.

3 When a tree is felled in a timber harvesting operation, the bole is removed (in the form of logs) but other wood—especially that in the branches and crown—remains on the forest floor. Forests tend to regenerate better if such woody debris is also removed.

Logging debris is used as woodfuel in the PWA operation. Photo: © J. Blaser

NTFPs was considered a tool for alleviating poverty because nearly 25% of the world's poor depend on forest resources (Fortini 2019). Even though reports of NTFP overharvesting are common in the literature, including with significant impacts on forest structure, a systematic review of the sustainability of NTFP harvesting concluded that, in nearly two-thirds of studies, NTFP extraction was sustainable (Stanley et al. 2012).

Two important factors influencing the sustainability of NTFP harvesting are the plant component harvested and the life history of the species (including pattern of growth, reproduction and pollination). For long-lived perennials such as shrubs and trees, the extraction of reproductive parts—fruits, flowers and seeds—tends to have high potential for sustainable harvesting (Ticktin 2015).

In terms of local livelihoods, approximately 75% of NTFP gatherers earn more than USD 2 PPP per day,[4] or more than the local wage (Stanley et al. 2012). Moreover, the markets for certain NTFPs, such as Brazil nut and açaí, have grown in recent years (Lopes et al. 2019). Brazil nut is important for local people in the forests of Bolivia and Brazil, and it is the only nut with an international market that is entirely harvested in mature natural tropical forests (Soriano et al. 2012). Açaí is collected from the abundant açaí palm, which grows along rivers, making collection relatively easy and transportation costs relatively low (Lopes et al. 2019).

Apart from the risk of overharvesting and causing changes to forest structure, imbalances between NTFP supply and demand can create problems, such as scarcity in some areas and a lack of markets in others (Weinstein and Moegenburg 2004). Local people often need to transport NTFPs over long distances, either increasing transport costs or involving middlemen. This reduces profit and increases dependence on intermediary transport, which may be unreliable; for perishable products, this increases the risk of loss (Weinstein and Moegenburg 2004).

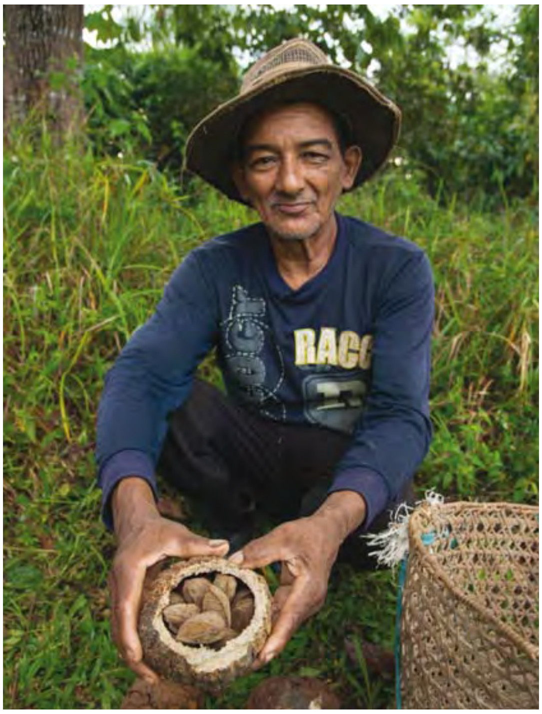
Even though tropical forests can satisfy multiple demands for goods and ecosystem services, integrated forest management approaches are still the exception (Guariguata et al. 2010). The concept of sustainable forest management (SFM) emerged in the 1990s (Poore 2003) to foster socially and environmentally sustainable harvesting practices, but it has focused on timber through the implementation of management plans to ensure sustainable timber yields (Fortini 2019). Approximately 53 million ha of tropical natural forests—22 million ha of protection forests and 31 million ha of production forests—were estimated to be under SFM regimes in 2010 (Blaser et al. 2011).

4 PPP = purchasing power parity, a method that uses rates of currency conversion to equalize the purchasing power of different currencies by eliminating the differences in price levels between countries (OECD undated).

Box 2: Abundance of Brazil nut in some Amazon Basin forests

Over several centuries, indigenous communities have had a major influence on both primary and secondary forests in the Amazon Basin. Small canopy openings (created through slash-and-burn agriculture), mainly on periodically inundated land adjacent to relatively flat lands (terraces), created a variety of successional forests of differing ages and secondary forest stands characterized by a relatively small number of tree and palm species. These areas have also been modified through enrichment planting with trees and other useful plant species that directly serve local livelihoods. A well described example is in the eastern Amazon Basin (Acre in Brazil and parts of the Peruvian and Bolivian Amazon), where old-growth, tall forest formations contain large numbers of Brazil-nut trees (*Bertholletia excelsa*). Today, it is believed that such formations are the result of traditional enrichment techniques carried out by indigenous communities over centuries (Dubois 1996). Even in the forest management unit of Precious Woods Amazon—far outside the natural range of the Brazil-nut tree—a large plot of Brazil-nut trees was discovered in what previously was considered untouched primary forest. Brazil-nut trees are protected from felling in the Brazilian Amazon because of their value in the provision of nuts. Secondary forests enriched with Brazil-nut trees are allowed to develop into nut-producing forests, which have a lower chance of conversion to crops and pasture (Paiva et al. 2011). Some experience in the combined management of timber and Brazil nut has been obtained in the Antimari State Forest in Acre, which is managed according to sustainable forest management criteria with considerable previous support from ITTO.[5]

5 For information on ITTO projects in the Antimari State Forest, see www.itto.int/project/id/PD248_03-Rev.4-F and www.itto.int/project/id/PD094_90-Rev.3-I



A Brazil-nut collector, Brazil. Photo: ©WWF/Zig-Koch

Core elements of multiple-use management for timber and non-timber forest products

Managing tropical forests exclusively for timber, generally through concession agreements, means the neglect of other products and services, on which many local people depend for their livelihoods. Only a few examples exist of efforts to combine the management of timber and NTFPs within the same FMU under a multiple-use management approach. Thus, such integrated approaches to the sustainable management of natural tropical forests remain elusive.

Given the ongoing depletion of moist tropical forests, it seems clear that new approaches are needed to complement the setting aside of a portion of the natural forest estate in protected areas. A broadening is needed of forest management, away from a singular focus on timber towards a multiple-use approach in which timber, NTFPs and ecosystem services such as the provision of freshwater, biodiversity conservation and carbon sequestration are valorized. This report focuses on the combined management of timber and NTFPs in forests classified and used as natural production forests in the tropics.

Blaser et al. (2011) estimated that 403 million ha of the 761 million ha of natural forests in ITTO producer member countries (as of 2010) are classified

Box 3: ITTO's work on non-timber forest products in multiple-use forest management

In partnership with several other organizations, ITTO co-convened an international conference on non-timber forest products in Beijing, China, in 2007. The aim of the conference, which was attended by about 120 people from 42 countries, was to bring together producers, traders and consumers to share experiences in promoting NTFPs in domestic and international trade. Among other things, the conference concluded that NTFPs are important to many communities, particularly the rural poor and among women, but the benefits of the NTFP trade are not always distributed equitably and markets are often informal, disorganized and open to exploitation. For many NTFPs, the value chain is not well developed and more value-adding at the local level could provide forest-based communities with significant benefits. There is a lack of normative guidance on the management of many NTFPs and a need to pursue sustainable multiple-use management of forests for all goods and services. Among other things, the conference recommended that governments and international organizations: support participatory processes to develop and improve legal and policy frameworks that encourage the production and trade of NTFPs and forest services, including by addressing land tenure, resource access, and user rights; ensure that these laws and policies allow and assist indigenous and local communities, especially women, to develop successful community-based forest enterprises; and ensure that such laws and policies also encourage the improved organization and equitability of markets for NTFPs and forest services at the local, national and international levels (ITTO 2009).

ITTO also fosters the development of NTFPs through projects, partnerships and other activities. For example, it has:

- promoted the establishment of agroforestry systems involving Brazil nut in Madre de Dios, Peru, with significant uptake by families settled in the area as an income-generating activity;
- assisted the development of the rattan sector in member countries of the Association of South East Asian Nations through the demonstration and application of rattan management and utilization technologies;
- assisted producer countries to identify strategies that balance the conservation and use of wild agarwood with the development of agarwood plantations;
- conducted research to support the sustainable harvesting of wild cacao;
- assisted the development of community-based ecotourism, such as in the Tacaná Volcano Biosphere Reserve area of influence on the border between Mexico and Guatemala and in the Emerald Triangle Protected Forests Complex in Cambodia, the Lao People's Democratic Republic and Thailand; and
- conducted research on the sustainable management and use of açaí in Brazil.

More information on ITTO's work on NTFPs, and its project portfolio, is available at www.itto.int

as production forests in the permanent forest estate.[6] and the remaining 358 million ha as protection forests. In 2010, approximately 131 million ha of natural production forests were being managed with legally approved forest management plans, which nonetheless focused almost exclusively on timber production. Fewer than 5 million ha could be classified as having a multiple-use management approach and, in most of that area, the focus of management was on ecosystem services (Blaser et al. 2011).

Managing an FMU solely for timber production no longer corresponds with the general concept of SFM. Multiple-use forest management has become entrenched in SFM—conceptually at least—as a means to achieve economically, socially and environmentally sound development in the tropics.

In broadening the scope of management in tropical production forests, in particular to manage for both timber and NTFPs in the same FMU, the following core elements need to be considered (Guariguata et al. 2010):

- the inclusion of both timber and NTFPs in forest inventories;
- the conceptualization of appropriate silvicultural and ecological management regimes;

6 The permanent forest estate is land, whether public or private, secured by law and kept under permanent forest cover. This includes land for the production of timber and other forest products, for the protection of soils and water, and for the conservation of biodiversity, as well as land intended to fulfil a combination of these functions (ITTO 2016).

- the evaluation of possible conflicts in the use of multipurpose tree species;
- the design of wildlife conservation strategies and regulated hunting approaches; and
- the development of tenure and access rights.

Each of these is considered below.

Forest resource inventories that include timber and non-timber forest products

In tropical forest countries, data are reasonably comprehensive for timber and woodfuel but are absent for all NTFPs except a few internationally traded products. Considerable effort is needed to integrate NTFPs into regular timber/carbon inventories. Such additional effort should include not only registering the presence of locally important NTFPs (traded or used locally for subsistence) but also estimating yields to guide future management. Many countries now require, by law, fully developed forest management plans (Blaser et al. 2011), and attempts have been made to improve the collection of data on NTFPs in timber production forests. In countries in the Congo Basin, for example, concessionaires record data on NTFPs in timber inventories, including wild meat and evidence of wild-meat hunting. Only a few timber companies use such data to value NTFPs, however. Complementary studies are necessary on the feasibility of undertaking data collection on NTFPs and (participative) mapping, which would also require additional human resources and financial means.

Companies whose operations have been certified by the Forest Stewardship Council (FSC), such as Industrie Forestière de Ouesso and Congolaise Industrielle des Bois (CIB) in the Congo and Precious Woods in Gabon, have made efforts to improve knowledge on NTFPs, particularly wild meat. Even if an NTFP is not explicitly part of a forest management plan, mapping its presence in a pre-logging inventory can help ensure its maintenance in the forest. In Borneo (Sarawak and Sabah, Malaysia, and Kalimantan, Indonesia), the sago palm (*Eugeissona utilis*), a basic food of local Penan and Punan people (Chai 2017), grows along ridgetops and can be damaged during the opening of skid trails for logging (Sheil et al. 2008). Awareness of this is a first step in avoiding such damage.

Even in cases where timber and NTFPs have high commercial value, the cost-effectiveness of implementing integrated inventories of timber and NTFPs may depend on the extent of biological similarity among products. In the community forestry concessions of Petén, Guatemala, distinct inventory protocols have had to be designed for timber and NTFPs, in particular for the highly valued xaté palm (*Chamaedorea* spp.), which occupies the forest understorey. Timber is harvested in annual compartments in rotations of several decades, but xaté palms take only 4–6 months to regain pre-harvest yields. Thus, producing inventories is complex and expensive (Goday et al. 2009). In contrast, large palms and tree species that bear NTFPs can be integrated into forest inventories more easily.

Overall, the integration of NTFPs into forest inventories and subsequently into forest management plans is a prerequisite for sustainable multiple-use forest management.

Ecology and silviculture for timber and non-timber forest product management

The biophysical compatibility of management for timber and NTFPs can be positively or negatively affected by the wide range of logging intensities applied across the forested tropics (Putz et al. 2001; Sist and Ferreira 2007).[7] This creates varying conditions for NTFPs and their management due to differences in the direct impacts of logging, such as the rate of tree mortality, changes in forest structure, the amount of solar radiation reaching the forest floor after logging, and soil compaction. The ecological attributes of the NTFPs are also important. For example, climbing palms—many of which, such as rattan,[8] are high-value NTFPs—usually benefit from logging-related canopy openings (if silvicultural treatments do not cut them away), and NTFPs that grow in the understorey may profit in logging gaps. In general, however, any beneficial post-logging effects on the growth and yield of NTFPs may be expected to be localized and short-term because timber management requires long rotation cycles of at least 25–40 years and timber volume may take 60 years to recover (e.g. in Amazon locations; Vidal et al. 2020, cited by Putz and Thompson 2021). These are important considerations for a combined forest management approach.

The few published works on the effects of selective logging on NTFP yields suggest compatibility at the level of forest stands. A review of the literature by Guariguata et al. (2010) indicated that, if selective single-tree harvesting and reduced-impact logging

7 In general, logging is heaviest in dipterocarp forests in tropical Asia, followed by African moist forests and then Amazonian forests.

8 Rattan is the common name for a variety of climbing palms in several genera, the most important being *Calamus* (see below and also the case study in Chapter 2).

are applied, the environmental conditions for NTFP growth are equivalent to those in unlogged forests within less than three years. In the Precious Woods Gabon concession, a considerable number of birds and large mammals returned to annual compartments within months of the cessation of logging operations (Z. Burilalova, personal communication, March 2020; see also Burilalova et al. 2015). This is due to the company's careful silvicultural management and reduced-impact logging, with the low rate of harvest of NTFPs and minimal logging impacts largely accounting for the observed compatibility of timber and NTFP management. Low-impact harvesting might not always favour such compatibility, however. For example, both the frequency and size of canopy gaps in forests logged in okoumé-rich forests may be insufficient to enable the light-demanding okoumé timber trees and other NTFP species to regenerate (Aeschlimann 2019).

Some silvicultural interventions applied in timber management may facilitate NTFP management objectives. For example, lianas in tree crowns can reduce fruiting in timber trees (Fonseca et al. 2009). Liana cutting, applied mainly as a way of reducing logging damage to residual trees and to improve worker safety, could be extended in managed forests to enhance fruit production in NTFP-bearing trees, as suggested for Brazil nut (Guariguata et al. 2010). PWA practises silvicultural treatments after selective tree harvesting that may benefit NTFPs: these include the removal of tree neighbours from future crop trees and "cleaning" logging gaps by removing remaining tree crowns (the latter operation is performed by local enterprises, which use the collected wood to produce woodfuel for electricity production). Such cleaning may assist the natural regeneration or enrichment planting of NTFP species such as palm trees and wild cocoa (*Theobroma cacao*).

Silvicultural systems applied in dipterocarp forests in Asia, such as shelterwood systems (which remove or reduce the main canopy layer), also appear ecologically and economically suitable for managing timber and light-demanding NTFP species (Ashton et al. 2001, cited in Guariguata et al. 2010). Existing treatments may require adjustment, however, to favour specific NTFPs, such as rattan, cardamom and damar resin. Reports are rare on how the management of NTFP species may affect the regeneration and development of valuable timber species.

Possible conflicts in the use of multiple-use tree species

Conflicts may arise over the use of a given tree species if it has value as both a commercial timber and an NTFP. This is especially likely when resource use is not clearly regulated, such as when there is an overlap between traditional and "legal" user rights (e.g. in timber concessions) (Guariguata et al. 2010). The greater the resource value (as either timber or an NTFP), the greater the conflict.

Generally, two types of situation can create conflicts:

1) when different stakeholders are involved in the extraction of different resources in the same forest; and, in a more complex case,
2) when different stakeholders are involved in harvesting different products from the same tree.

Many timber species in tropical America are also highly valued for their NTFPs. Examples include *Dipteryx odorata* (cumarú), a hard, dark timber species; *Hymenaea courbaril* (algarobo, jatoba), a timber species used as an alternative to mahogany; *Tabebuia serratifolia* (yellow ipé), an extremely dense hardwood; and *Tabebuia impetiginosa* (ipé preto). The barks of yellow ipé, ipé preto and jatoba are valued for their medicinal properties, and oil is extracted from the seeds ("tonga beans") of cumarú for cosmetic and medicinal purposes. An option for minimizing conflicts over use is the legal protection of a species from logging when the economic and social values of an NTFP equal or exceed the timber value. Such protection is currently conferred on Brazil-nut trees in Bolivia, Brazil and Peru because of the important economic role played by the nuts in rural families (Guariguata et al. 2010).

Conflict over use is common in the Congo Basin. In Cameroon, more than half the 23 timber species exported also produce valuable NTFPs (Ndoye and Tieguhong 2004). In the Congo Basin, the three most-exploited timber species—*Triplochiton scleroxylon* (samba, wawa, ayous), *Entandrophragma cylindricum* (sapelli) and *Milicia excelsa* (iroko, African teak)—are also sources of medicines and food. Okoumé (*Aucoumea klaineana*) is the main timber species commercialized internationally in Gabon. A light-demanding species, okoumé grows well when provided with adequate silvicultural conditions, and it constitutes the backbone of sustainable timber management in Gabon's natural forests. The species also produces valuable NTFPs: its resin has anti-protease and anti-inflammatory properties (Praxede-Mapangou 2003) and its leaves and small branches are used in local medicine (Clark and Tchamou 1998, cited in Van Rijsoort 2000).

In Cameroon and the Democratic Republic of the Congo, forestry laws clarify the obligations of logging companies towards local people, with provisions aimed at avoiding situations in which timber harvesting prevents villagers from exercising their forest user rights. To meet this objective, local communities and timber companies should work together to reach agreements on maintaining tree species over which conflicts may arise. In Cameroon, however, inventorying NTFPs as part of timber censuses is done at the discretion of concessionaires (GIZ 2006, cited in Guariguata et al. 2010).

Another means for avoiding conflict over use is the spatial separation of management units for timber and NTFPs. The feasibility of this option depends on, among other factors, the nature of the NTFP in question, its habitat requirements, and the overall size of the forest management area.

Managing conflicts over use requires a good understanding of the characteristics of the tree resource (both timber and NTFPs). For example, for tree species that produce edible fruits collected as an NTFP, fruit production may peak in intermediate diameter classes (Guariguata et al. 2010); in this case, trees in large diameter classes that produce few fruits could be subject to timber harvesting without greatly affecting the supply of the NTFP. This type of information is scarce, however, and needs to be increased in all tropical forest regions.

Designing wildlife conservation strategies and regulated hunting approaches

Many wildlife species in tropical forests are important NTFPs. Most vertebrate species can persist in natural tropical production forests if indirect impacts caused by (for example) hunting, forest fragmentation and forest fire are controlled (Meijaard et al. 2005). These indirect impacts are widespread and pervasive, however, particularly unregulated hunting for wild meat (Guariguata et al. 2010) in the permanent forest estates of Africa and Southeast Asia. The overharvesting of wild meat is most often perpetrated by outsiders at the expense of those with prior, legitimate claims to forest wildlife, especially indigenous communities.

The expansion of commercial timber operations into previously undeveloped forest areas means the building and maintenance of roads and other infrastructure and an associated influx of forest workers and support services. The increased presence of outsiders in a forest area can pose a risk to the sustainability of NTFP resources, especially those products with significant market value.

This is particularly true for illegal hunting, including by forest workers for subsistence purposes and by commercial operators. Such hunting poses a considerable risk to wildlife conservation and must be viewed with concern by forest managers, who should take effective measures to avoid poaching, control people employed by the company and regulate wildlife conservation and local hunting in the timber concession area.

The compatibility of timber harvesting and sustainable wildlife management may be contingent on the exercise of several interrelated measures. One of these is ensuring that timber concessionaires take steps to ensure that their employees do not exacerbate hunting, such as by banning them from purchasing wild meat and providing them with alternative sources of protein. The certified timber companies operating in Cameroon, the Congo and Gabon have adopted such measures, in partnership with non-governmental organizations. Another measure is to allow rural communities to sell wild meat for local consumption in nearby urban centres. For example, communal hunting areas have been designated for abundant and ecologically resilient species in the CIB timber concession in northern Congo.

Although not really countable as an NTFP, ecotourism for wildlife observation is a potential source of revenue for local communities, as envisaged by Precious Woods Gabon, but timber companies and communities generally lack the know-how. Conservation non-governmental organizations could assist in developing this livelihood option by providing expertise, helping communities develop ecotourism capacity, and meeting some of the startup costs through their own fundraising.

Guariguata et al. (2010) summarized the effects of selective logging on aquatic wildlife. They noted that, in the hilly and mountainous landscapes of Borneo, many locally important fish species are known to be sensitive to increases in stream sediment when logging roads are built (Meijaard et al. 2005). Locating logging roads away from streams and minimizing their width may help reduce sediment loads and therefore the impact on fish species. A study in an Amazonian timber concession found no medium-term loss of fish species from forest streams in areas subject to reduced-impact logging (including minimizing soil damage) compared with unlogged areas, although changes in the abundance of some species were detected (Dias et al. 2010).

Xaté palm, Peten, Guatemala. Photo: Rainforest Alliance

Forest tenure and access

Multiple-use management for timber and NTFPs requires an understanding of who has legal rights and responsibilities for management decisions affecting both types of product (Guariguata et al. 2010; ITTO 2009). Individual, comprehensive ownership rights are the exception in most tropical forests. Often, forest tenure is an overlapping bundle of rights, including those to access and harvest the resource, manage it and exclude others, and to sell or transfer resource rights to others (Schlager and Ostrom 1992). Forest concessionaires hold partial sets of rights, and local stakeholders may hold certain rights over the same resource. Clearly, the types of rights held, and the presence of multiple rights-holders, will influence the compatibility of multiple-use management for timber and NTFPs and the prospects for achieving SFM.

In the community forest concessions in Petén, Guatemala, the rights to xaté are held largely by stakeholders outside community timber concessions, and this potentially creates conflict over resource use. A similar situation exists in *ejido* forests[9] in Quintana Roo, Mexico, where overlaps exist between those with rights to timber and those with rights to harvest chicle. In northern Bolivia, conflicts have arisen between industrial timber concessions superimposed on customary properties (*barracas*) and on agro-extractive communities dependent on Brazil-nut extraction (de Jong et al. 2006). The potential for excluding legitimate rights-holders from forest benefits may undermine the prospects for integrated management regimes (Guariguata et al. 2010).

9 In Mexico, *ejidos* are the village lands communally held in the traditional Mayan system of land tenure that combines communal ownership with individual/association use. An *ejido* consists of forest, cultivated land, pasture and the *fundo legal* (townsite).

Pathways to multiple-use management for timber and non-timber forest products in tropical production forests

Taking into account the issues described above, multiple-use management in tropical production forests can have various forms, including the following:

- managing commercial timber species that also produce valuable NTFPs;
- managing species that produce timber and species that produce NTFPs in the same area;
- combining the harvest of commercial timber and palm species; and
- increasing NTFP production in timber production forests through enrichment planting.

Managing commercial timber species that also produce valuable non-timber forest products

As noted above, many examples exist of valuable timber species that are also valued for their NTFPs. In the Amazon, studies cited in Guariguata et al. (2010) indicate that 47% of the 65 timber species currently traded in Pará, Brazil, also have documented non-timber uses. The situation is similar in African and Asian forests (Table 1).

It is possible to integrate the production of timber and these NTFPs into silvicultural systems in ways consistent with the sustainable management of the species. Box 4 examines the case of two highly exploited timber species, sapelli (*Entandrophragma cylindricum*) and tali (*Erythrophleum ivorense*),[10] that also host caterpillars that are a significant source of protein and are in high demand in rural and urban markets in the Congo Basin. In general, however, little information is available on the value of commercially harvested timber species for their NTFPs.

Managing species that produce timber and species that produce non-timber forest products in the same area

Examples exist worldwide where commercial timber harvesting and NTFP harvesting are done in the same area. On the Yucatán Peninsula, Mexico, for example, highly priced mahogany (*Swietenia macrophylla*)

10 There are two closely related species of *Erythrophleum*, *E. ivorense* and *E. suaveolens*; the two species share many uses, vernacular and trade names, and properties, and confusion between them is common.

Box 4: Sapelli and tali—valuable timber species in the Congo Basin providing protein

Sapelli (*Entandrophragma cylindricum*) and tali (*Erythrophleum ivorense*) are among the most important timber species harvested in the Congo Basin. They also host the edible caterpillars *Imbrasia oyemensis* (sapelli) and *Cirina forda* (tali), which are important for the nutrition and income of rural and urban communities (Muvatsi et al. 2018). Tali trees of sizes suitable for timber harvesting are the main source of *C. forda*; given the low density of harvestable sapelli, the bulk of *I. oyemensis* caterpillars occur on pre-commercial individuals. Caterpillar production can be maintained through management practices such as minimizing the logging of poorly formed or hollow individuals of sapelli and tali; imposing high minimum diameter limits for timber harvesting; retaining seed trees; prohibit logging on slopes and in riparian zones; favouring the harvesting of caterpillars on younger trees; and setting aside caterpillar collection zones. Planning and management to minimize conflicts between timber and caterpillar harvesting should be based on negotiations with local communities.

occurs in the same semi-deciduous moist forests as chicle (also known as chicozapote) (*Manilkara chicle, M. zapote*) (Richards 1992). Chicle is the basis for natural chewing gum; it is used traditionally by the Mayan people and was the original raw material of Wrigley's chewing gum, a popular commercial brand. The boom in chicle sap markets ended in the 1950s, however, when a synthetic gum was created to replace natural sap, contributing to the economic decline of chicle trees. Today, the ancestral production techniques used by the Maya are being deployed to produce chicle for organic brands such as Chiczá.[11] Several large *ejidos* manage their forests for chicle sap extraction and timber production involving mahogany and other species.

In South and Southeast Asian humid forests, numerous species of dipterocarp produce very valuable timber, and others produce widely used and commercialized resin, such as damar (see case study in Chapter 3). Gutta-percha, a medium-sized tree, occurs in mixed dipterocarp forests; the latex it produces was once a highly appreciated and internationally traded commodity used as an insulator for electrical wiring and underwater telegraph cables (a purpose for which it is well suited because it is bio-inert and not attacked by marine plants or animals). Today, this NTFP is being revived as an alternative to synthetic materials. With its value increasing, managing the species in forests also used for timber production is a silvicultural challenge.

A special combination: harvesting commercial timber species and palm tree species

Palm species are common in natural forests throughout the tropics. The production of various palm-based NTFPs can be complementary to timber production because palms are often particularly abundant in areas not directly in competition with valuable timber species. Palm trees often require special conditions to grow, such as swampy or otherwise moist areas and specific sandy soils. Palm species with considerable potential as NTFPs in the Amazon include açaí, aguaje (*Mauricia flexuosa*) and babassu (*Attalea speciosa*—Box 5). In Guatemala, local communities manage xaté palms in timber production forests. The NTFP vegetal ivory (*Phytelephas* spp.), also known as tagua, grows in tropical forests in a region stretching from southern Panama to the Pacific forests of Colombia and the western Amazon.

Rattan is one of the most valuable NTFPs in tropical forests. Systems for rattan production are well-established in Asia (Sunderland 2001), including in permanent production forests.

Rattans are widespread throughout Central Africa and form an integral part of subsistence strategies for many rural communities, but the commercial rattan sector is relatively undeveloped. Although trade is limited, rattan is a significant source of revenue for local people in Central African forests, rivalled only by wild meat (Sunderland and Ndoye 2004). Three rattan types are generally used commercially in the subregion: *Laccosperma secundiflorum*, *Eremospatha macrocarpa* and *Laccosperma robustum* (Sunderland and Ndoye 2004). Rattans in Central Africa are harvested almost exclusively from wild populations and are generally considered an open-access resource.

Guariguata et al. (2008) concluded that, beyond rattan, other (albeit limited) experiences exist in the implementation of multiple-use management for timber and palm-based NTFPs with a relatively high degree of compatibility. Generally, such management requires low timber harvesting intensities as well as the temporal, spatial and social segregation of timber and palm-based NTFP extraction.

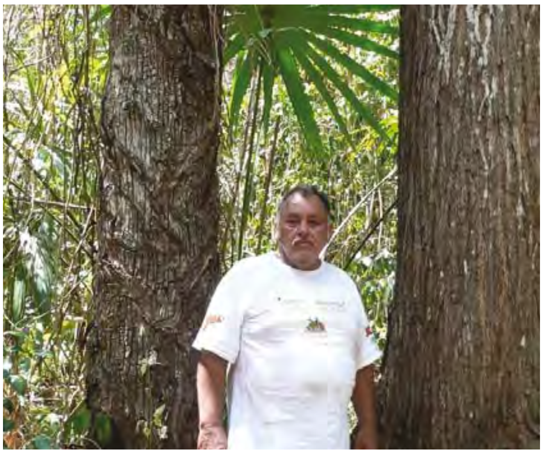
11 www.chicza.com

Box 5: Babassu—a newcomer in multiple-use production forests?

Babassu (*Attalea speciosa*), also known as babaçu, is a large palm capable of attaining a height of more than 20 m; it occurs naturally throughout the Amazon. Related species occur in moist and moist deciduous forests in Mesoamerica and the Colombian Pacific. In the Amazon, babassu is a dominant successional species in the Brazilian states of Maranhâo, Pará, Piaui and Tocantins. The species is a characteristic pioneer species, and it easily colonizes open cerrado and abandoned pasture areas.

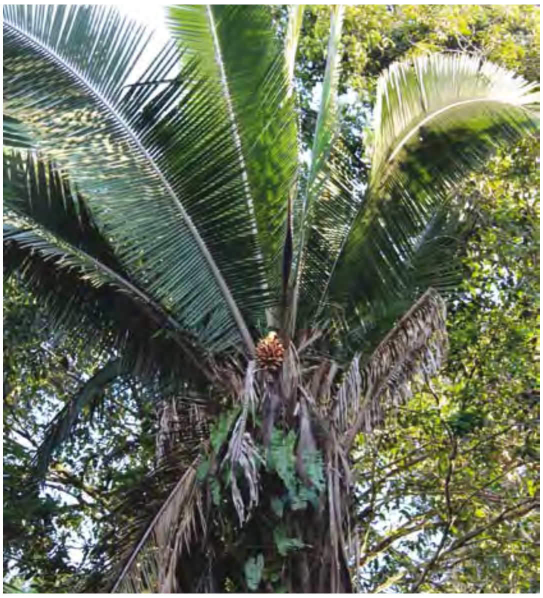
Babassu has commercial value because its seeds contain an edible oil, which is also used in skin cleansers and other skin-care products and also, more recently, as a high-grade biofuel. The fruit is used to produce a flour that is highly appreciated locally and commercialized as a nutritional supplement and also in medicines, beauty aids and soaps and as a beverage (May et al. 1985). Babassu leaves are used as thatch for local houses and, like coconut leaves, can be woven into mats and walls for low-cost housing.

In the eastern Amazon, a substantial share of local household incomes is derived from working as *quebradeiras de coco babaçu* (babassu nut breakers), who collect and crack open babassu fruit to extract oil from the kernels. More than 100 000 families are estimated to depend on babassu for various subsistence purposes, and the income generated by *quebradeiras* from selling oil and other babassu products is crucial for the survival of many families (May et al. 1985; Hill 2005). Babassu is a promising tree for enriching degraded production forests in early stages of succession.



Chicle and mahogany, Quintana Roo, Mexico. Photo: © J. Blaser

Rattan collection in a Mindanao production forest, the Philippines. Photo: © J.Blaser



A babassu tree with fruit in the Amazon. Photo: © T. Claas/PWA

Enrichment planting with non-timber forest product species in tropical timber production forests

Enrichment planting comprises a set of techniques designed to increase the density of commercially valuable tree species when natural regeneration is insufficient to meet management goals. Although not yet widely practised, enrichment planting can also be deployed to increase the density of species that produce NTFPs. Such a practice could be used, for example, in forest areas with good access to roads, such as in well-established long-term concession

Table 1: Examples of valuable tropical timber species and their potential as non-timber forest products

Timber species		Location	Non-timber forest product (NTFP)	Use	NTFP value
Scientific name	Common name				
Aucoumea klainena	Okoumé	Equatorial Guinea, Gabon	Resin	Medicinal	+
Baillonella toxisperma	Moabi	Congo Basin	Fruits	Oil, wildlife food	+
Entandrophragma cylindricum	Sapelli	Congo Basin	Caterpillars	Food (protein)	+
Erythrophleum ivorense	Tali	Congo Basin, West Africa	Caterpillars	Food	+
Bertholletia excelsa	Castaña	Eastern Amazon	Nut	Food	+++
Carapa guianensis	Andiroba	Amazon, Central America	Seed	Oil	+
Copaifera spp.	Mora	Amazon	Copaiba oil	Health care	++
Hymenaea courbaril	Jatoba	Amazon	Bark, seeds	Medicinal	+
Manilkara spp.	Maçaranduba	Amazon	Latex	Material use	+
Tabebuia impetiginosa	Ipé, amapá	Amazon–Mexico	Bark	Health care	+
Shorea robusta	Sal	Indian subcontinent	Seeds, leaves	Salbutter, oil	++
Dryobalanops aromatica	Borneo camphor, kapur	Borneo	Bark	Medicinal, oleoresin	+
Dipterocarpus alatus	Yang na, kanyin	Andamans, Bangladesh, Indochina	Resin	Oleoresin	+
Other genera of *Dipterocarpaceae–Balanocarpus, Hopea, Shorea*	Merbau, lauan, mersawa,	Indonesia, Malaysia, Philippines	Damar resin	Health/beauty, industry	++

Note: + existing local value chain; ++ recognized national and international value chain; +++ globally traded.

areas, community forests and large landholdings pursuing long-term forest management (e.g. "legal reserves" in the Brazilian Amazon). In such situations, where the forest's long-term security is assured, there are good reasons to invest in enrichment planting with suitable NTFP species. For example:

- The production of NTFPs in large forest areas will increase monetary returns from SFM, thereby providing an incentive for forest owners to maintain their forests as an asset (Keefe 2008).
- NTFP management and use is an effective way of earning annual income from production forests managed on rotational cycles (e.g. spanning 20–40 years) that otherwise might not yield returns for lengthy periods.
- NTFPs can add value to accessible forests in areas where timber harvesting is not permitted (e.g. in riparian zones and steep terrain). Also, certain NTFP species could be introduced as enrichment plantings in naturally open forest areas where, due to specific edaphic conditions, forest canopies are not closed. Thus, NTFP production can be physically separated from timber production areas within the same FMU, thereby avoiding potential problems between silvicultural interventions for timber species and NTFP management.
- NTFPs provide work opportunities during the wet season, when many labourers in the forest sector are otherwise underemployed or unemployed.

Enrichment planting with NTFPs requires two conditions: a suitable growing environment for the planted species, and a willingness on behalf of landholders to invest in planting NTFPs, returns on which might take several years. Ecological factors such as site conditions and treatments, and socioeconomic factors such as tenure security, cost and financing, also affect the feasibility of enrichment planting. The scale of planting may determine the impact of these factors (Keefe 2008).

Costs associated with enrichment planting include the direct costs of labour, equipment, training, site preparation, maintenance and the transport of materials to and from markets. There are generally no significant opportunity costs, assuming that a decision has already been made to ensure the integrity of the forest in preference to other land uses.

The following are examples of possible approaches to enrichment planting with NTFPs.

- **Enrichment planting with NTFPs immediately after a logging intervention.** Examples of this scenario might be the introduction of wild cocoa in tropical America and African plum and

Fruit of allanblackia, Ghana. Photo: © J. Blaser

allanblackia in tropical Africa. Palms (e.g. açaí, xaté, babassu and rattan) for the production of palm hearts, fruits, oils, ornaments and other products merit careful study from a social viewpoint. Decisions on the NTFP species to be used in enrichment planting should be based on clear ecological and economic criteria (e.g. access to seeds, ecological suitability, time to first production, silvicultural considerations and potential markets).

- **Enrichment planting with commercial timber species that simultaneously provide NTFPs.** Examples of such timber species include ipé (*Tabebuia serratifolia*) in the Amazon, okoumé (Box 6) and sapelli in the Congo Basin, and various dipterocarp species in Southeast Asia. In many cases, the non-destructive harvesting of NTFPs can commence when trees are relatively small. Timber production, on the other hand, generally requires longer growing times to attain minimum harvestable diameters (based on a country's regulations). The harvesting and use of NTFPs can generate income in a forest area otherwise yielding few immediate economic returns before timber harvesting takes place.
- **Enrichment planting to add value to degraded forests.** In forests that are degraded due to pressures such as unsustainable logging, woodfuel cutting, shifting cultivation, wildfire, storms and pests and diseases, enrichment planting can install tree species that, over time, prepare the forest for intensified agroforestry systems, for example with secondary species such as *Parkia gigantocarpa* and *Schizolobium amazonicum* in the Amazon.

A study in the Brazilian Amazon found that enrichment planting with timber species can help ensure multiple timber harvests but may be difficult to sustain without short-term financial benefits (Keefe 2008), such as those provided through multiple-use management, including NTFPs. A social appraisal of enrichment planting may reveal social benefits that would justify governmental, financial and policy support.

Box 6: Okoumé—a renowned timber species with other (secret) values

For several decades, okoumé (*Aucoumea klaineana*)—the main commercial timber species in Gabon—has been subject to successful enrichment planting in harvested natural forests. In addition to its value as timber, the leaves and bark of okoumé can be used for medicinal purposes. The harvesting of side branches to produce these products can take place in a tree's early stages of growth, up to immediately before the tree is harvested for this timber, without negative impacts on tree growth or timber value. Such combined use could also provide a basis for effective community–company partnerships.

Source: Based on Clark and Tchamou (1998), cited in Van Rijsoort (2000).

Enrichment planting with NTFP species in tropical production forests might be best implemented through close partnerships between forest owners and local communities with the aim of achieving joint benefits.

Legal constraints on including non-timber forest products in timber management schemes

The potential for conflicts in the use of timber and NTFPs is noted above, including legal issues relating to rights of resource use and tenure. A fundamental problem in many natural tropical production forests is that forest concession contracts are issued for predetermined periods and for the management of a single forest product, in most cases commercial timber but also, exceptionally, particular NTFPs (e.g. in the case Brazil nut). As also described above, overlaps can occur in the rights of different users in the same FMU. This needs synergies and common planning frameworks to enable the sustainable management of all resources.[12] In most tropical countries with considerable remaining forest

12 An issue that has grown exponentially over the past two decades in all humid tropical forest areas is the overlay of forest management (e.g. through timber concessions) and concession rights to use soils and underground for mining and oil exploitation in the same area. Mining, oil and gas extraction imply major trade-offs for SFM.

resources, forest-user contracts are given out for single purposes; in some cases, such contracts are given out on the same area to different stakeholders to exploit different types of product. Few forest laws recognize the multiple-use management of a given FMU. New types of agreements are needed for multiple-use management that enable forest managers (e.g. a long-term concession-holder) and owners to implement forest management systems encompassing the commercialization of both timber and NTFPs. These could be in various forms, such as concession agreements that entrust such management to forest managers. Alternatively, co-management agreements could be put in place with local communities providing a division of roles and responsibilities; for example, a concession-holder might be responsible for the development of a business plan for NTFP management, including investment and market analysis, and local partners (community-based or private enterprises) might be responsible for NTFP management and extraction.

It is generally recognized that a fundamental shift in thinking on NTFPs is needed in forest management agencies and among policymakers (Guariguata et al. 2010). For example, Central African countries still lack comprehensive, well-designed policies to support and promote a formal NTFP sector that could be applied in the many timber production forests in the subregion. Such policies could include an understanding of traditional management and control of NTFPs; measures to monitor NTFP exploitation and establish sustainable harvesting levels; measures to minimize the impacts of other forest uses on essential NTFPs; amendments to tax regimes to encourage enterprises based on NTFPs; the provision of favourable credit for small producers and cooperatives; and the provision of information on NTFP markets (Guariguata et al. 2010). Fundamentally, there is a need to clearly define rights to access and control resources and to ensure that such rights are properly recognized in the law.

Unsustainable and illegal harvesting of non-timber forest products in tropical production forests

Commercial timber activities can directly damage the production of NTFPs if not taken into account in forest management planning (which is the case for certified forest management operations, in which this issue is addressed in harvest planning). Wildlife poaching is perhaps the most publicized risk (Box 7), and another is the case of agarwood (*Aquilaria malaccensis*), also known as eaglewood or gaharu, a small to mid-sized tree. The wood of this species is highly valued for its fragrance and is used to produce incense, perfumes and various other products (Box 8 and the case study in Chapter 3). The agarwood population in natural forests has largely been destroyed in Southeast Asia by illegal collectors (usually outsiders, including workers in timber concessions), and there is considerable concern about the species's conservation status. Agarwood is listed as vulnerable in the International Union for Conservation of Nature (IUCN) Red List and considered critically endangered in a number of Southeast Asian countries.

Box 7: The threat to wild meat in timber concessions

The presence and expansion of commercial timber operations by concessionaires or landowners in forests, some not previously opened up to commercial activity, also means the building and maintenance of roads that provide general access to the forest. Roads bring the workforce for timber harvesting and processing, as well as other people. Direct, easy access to such forest areas and the presence of outsiders in a forest area constitute a risk to the sustainability of NTFPs, especially those with a high market value, either nationally or internationally.

Perhaps the biggest risk for NTFPs is illegal hunting (poaching)—both subsistence hunting by forest workers and commercial hunting. Hunting for wild meat is widespread in the Congo Basin and remaining natural forests in West Africa. Meat from wild animals is considered a special delicacy in many African countries and is expensive (Luiselli et al. 2020). Accessible forests in the Congo Basin and Southeast Asia are also highly exposed to hunting for other purposes, such as ivory, products made from rhino and tiger parts that are believed to have medicinal or other properties, and the live wildlife trade (e.g. monkeys as pets). These issues are of huge concern, not only for the conservation community but also for responsible forest managers. Avoiding poaching, therefore, is a crucial aspect of timber production in many tropical forests and requires a systematic approach involving forest managers, concessionaires, local communities and governments.

Box 8: The moving frontier of agarwood

The Indian subcontinent was the main source of agarwood for centuries, but the tree had become scarce there by the end of the 1950s. The focus of its exploitation then shifted to the Mekong subregion, but this was hindered in the 1960s and 1970s by war (in some cases, tree damage caused by the war increased the production of agarwood, providing a source of income for armed forces). Agarwood extraction intensified in Indonesia and Malaysia from the 1970s as demand increased, especially in the Middle East and China. From the mid-1980s, traders focused on the collection of wild agar in Borneo, where the resource lasted about ten years; new sources of the product were discovered in Irian Jaya and then, in the early 2000s, in Papua New Guinea. Agarwood is still being produced in the Mekong subregion, Sumatra and Kalimantan but is increasingly hard to find, and quality has declined. Agarwood species are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora; efforts are underway to produce agarwood in plantations (ITTO and CITES 2015).

Source: Goloubinoff et al. (2004).

In Cameroon, moabi (*Baillonella toxisperma*) is so highly valued for its timber that overmature trees are often felled even when the wood output is extremely small. The species is also a major source of food and oil for local people, and it is an important habitat component for many mammal species, including elephants and great apes.

Potential of and constraints on multiple-use forestry that combines timber and non-timber forest products

Literature is limited on conflicts between timber and livelihood-based non-timber uses. There is some evidence, however, that it is possible to develop management approaches that accommodate both uses in timber production forests where long-term commitment exists.

In their literature review on NTFPs in logged-over tropical forests, Rist et al. (2011) found that 82% of reviewed articles addressed negative impacts on the availability of livelihood-relevant NTFPs, most commonly due to conflicts over use and the indirect impacts of logging. Positive impacts were also identified: for example, the removal of canopy trees can provide conducive growing conditions for light-demanding plant species, including some that produce NTFPs. Despite the considerable impacts of existing logging practice on livelihoods, the authors concluded that there was evidence to support enhanced compatibility between timber extraction and the subsistence use of NTFPs.

The majority of the existing literature involves economic appraisal of the role of NTFPs in rural livelihoods, and only limited research exists on the function of NTFPs in local trade and subsistence. This is an important gap: documenting and building on the often-elusive land-use practices of local people can provide an effective foundation for broader multiple-use forest management.

Responsible forest management that includes low-impact logging based on adequate planning (e.g. ecologically sensitive timber harvesting) can contribute to local livelihoods. Logging can also degrade valuable NTFP resources, however, thereby jeopardizing the livelihoods of forest-dependent communities. The impact of management decisions on NTFPs in production forests and thereby the economic, social and cultural well-being of forest-dependent and forest-adjacent communities must be taken into account.

Accommodating the needs of forest-dependent people is a crucial issue in tropical production forests in the Amazon (e.g. Guariguata et al. 2012; Cronkleton et al. 2012; Rist et al. 2011; Sabogal et al. 2013), the Congo Basin (e.g. Ndoye and Tieguhong 2004; Sabogal et al. 2013) and Southeast Asia (e.g. Meijaard et al. 2005; de Beer and Guerrero 2008; Sabogal et al. 2013). Management approaches that ensure the sustainable production of timber and NTFPs have considerable potential to address both livelihood needs at the local level and the long-term security of forest stands.

Conclusion

Given the growing demands on tropical forests for the many goods and ecosystem services they provide, multiple-use management approaches are essential. As Sabogal et al. (2013) concluded, multiple-use forest management in tropical production forests remains a barely operational concept, however, due to various economic, technical and administrative constraints. Timber is still the only forest commodity with major lucrative markets; the tropical timber sector is based on a reliable body of technical knowledge and makes a significant contribution to the economies of many tropical countries. The dominant model of timber harvesting is being undermined in some regions, however, by the ever-increasing number of investors interested in agro-industrial and mining projects, for which the financial benefits can be much higher than those associated with sustainable timber harvesting. Multiple-use forest management could increase the economic benefits of SFM. Forest certification[13] and timber legality schemes (e.g. FLEGT[14]) could help support the implementation of multiple-use management.

It needs to be underlined, however, that the compatible management of timber and NTFPs is complex, multifactorial and context-dependent. Compatibility is possible in some situations but may be difficult to achieve in others. Note also that this conclusion, also drawn by others (e.g. Guariguata et al. 2010; Rist et al. 2011; Sabogal et al. 2013), is speculative given the scarcity of studies on economically and socially proven multiple-use approaches to timber and NTFP management in the tropics.

Although NTFPs are extremely important for local livelihoods throughout the tropics, and many NTFPs are traded in significant quantities at the local, national, regional and global scales, data on their long-term use and economic value remain scarce. Moreover, the management of NTFPs is often ad hoc, and little is known about their sustainability at the local scale. Integrating NTFPs into broader forest management approaches would be an important means to support the regulation of their harvesting and trade and thus the broader aims of SFM.

Ideally, the process to develop multiple-use forest management approaches in tropical production forests should begin with land-use planning because it implies a thorough assessment of biophysical, social, regulatory and institutional aspects. Overall, two broad approaches could be taken:

1) Improve existing situations on a case-by-case basis, particularly where forest management is entrusted to long-term concession contracts (either community-based or private). Inventories, management planning, harvesting and marketing would address both timber and NTFPs within an overall concept of managing forests and their products and services sustainably.
2) Develop new management regimes that explicitly encourage the sustainable production of timber and NTFPs, and the delivery of ecosystem services, over long timeframes.

The core idea is to explicitly enhance both timber and NTFP values. Approaches for optimizing compatibility between management for timber and for NTFPs must be scaled to the size of the forest area to be managed (i.e. the FMU), the silvicultural system to be applied, including harvest planning and intensity, and organizational aspects of managing (in the same area) a range of forest products and services. The dynamics of multi-actor partnerships—for example between a forest concession-holder and local communities—must be clearly defined, and the necessary technical, organizational and financial capacities for multiple-use management must be incorporated into tropical forestry curricula (Guariguata et al. 2008).

The relatively few but well-established long-term forest management operations in the Amazon and the Congo Basin in particular (most of which are certified) could provide means for developing the concurrent management of locally important NTFPs. About 10 million ha of well-managed tropical timber production forests (Blaser et al. 2011) could be enhanced by the incorporation of important NTFPs into management regimes. This would require the assessment of biophysical, social, regulatory, economic and institutional aspects so that trade-offs can be minimized among stakeholders. Sabogal et al. (2013) provided examples from the three tropical regions of partnerships between local forest users, the private sector, non-governmental organizations and civil society that have facilitated incorporation of NTFPs into the management regimes of timber-oriented models. Important considerations include the scale of management, the intensity of timber and NTFP harvesting, and the modes of extraction. Managing tropical forests for multiple products, ecosystem services and stakeholders requires processes for negotiation and shared decision-making—going beyond discussion platforms and committees designed to bring together local users and forest concessionaires and forest industries, which are mandated by law in some tropical countries (Cerutti et al. 2017).

13 WWF (undated) defined forest certification as "a mechanism for forest monitoring, tracing and labeling timber, wood and pulp products and non-timber forest products, where the quality of forest management is judged against a series of agreed standards".

14 The European Union Forest Law Enforcement, Governance and Trade (FLEGT) programme, which was launched in 2003, aims to reduce illegal logging by strengthening sustainable and legal forest management, improving governance and promoting trade in legally produced timber worldwide; increasingly, it is also taking NTFPs into account.

2 OVERVIEW OF WELL-ESTABLISHED NON-TIMBER FOREST PRODUCTS

This chapter presents three examples of well-established NTFPs in humid tropical forests. For each, it examines the factors and strategies that have enabled the sustainable harvesting of the NTFP and are now supporting continued success and the challenges that have arisen in maintaining a sustainable NTFP management regime.

Two large Brazil-nut trees (back centre) in the Antimari State Forest, Brazil. Photo: J. Blaser

Brazil nut (*Bertholletia excelsa*)

Common names: Brazil nut, Para nut, Amazonian nut, castaña

Occurs in: Western Amazon: Brazil, Bolivia and Peru. Dominant tree in the forests

Harvesting season: October–March

Harvesting yield: up to 470 nuts/tree/year

Main use: edible nut, export product

Substitute: sapucaia nut

Tree density in natural forest: 1–26 trees/ha

Harvesting practice: collection of fruits from the ground

Brazil nuts. Photo: © WWF/Zig-Koch

Bertholletia excelsa is a large tree, attaining a height of up to 50 m and a diameter at breast height (dbh) of up to 3 m (Zuidema 2003). The species occurs throughout the Amazon but is most abundant in the Brazilian part, particularly the states of Acre, Amazonas, Pará and Rondônia. *Bertholletia excelsa* is common in the department of Madre de Dios in Peru and the departments of Beni, La Paz and Pando in Bolivia (Zuidema 2003); it grows in permanent dry forest areas (*terra firme*) at densities that can exceed 26 trees per ha (Zuidema 2003).

Brazil nut has been harvested commercially since the mid-1600s (Kainer et al. 2007). The international trade started in the second half of the nineteenth century—a rubber boom attracted workers from outside the region and, when the rubber market collapsed, many of those workers refocused on the extraction of other forest products, especially Brazil nut; by the 1950s, Brazil nut was Bolivia's main traded NTFP (Guariguata et al. 2017). Most Brazil nuts are consumed in nut form, but the nuts can also be used in processed food products such as cookies and oils and in the production of cosmetics (Zuidema 2003). Brazil nuts are high in selenium, which is associated with various health benefits (Zuidema 2003; Dumont et al. 2006). Brazil nut is the only globally traded seed harvested entirely in the wild (Guariguata et al. 2017).

Brazil-nut trees start producing fruit at about eight years of age, with yields increasing up to 12 years to a plateau of 450–500 nuts per tree annually (SEBRAE 2016). The nuts (i.e. the seeds) are encased by a woody fruit containing 10–25 nuts (SEBRAE 2016). Harvesters collect the fruit when they fall to the ground during the rainy season and open them with machetes; the nuts are traded with and without shells. The price of unshelled nuts tripled between 2005 and 2016 (Silva 2017) and, today, Brazil nut is the most economically important NTFP worldwide (Rockwell et al. 2015). Combined, Bolivia, Brazil and Peru exported more than 35 million kg of nuts in 2012 (Shanley et al. 2016). Brazilian firms once dominated the export market of Brazil nut to such an extent that the globally recognized name for the fruit is that of their country (Coslovsky 2014). By 2013, however, Bolivia was the main exporter of Brazil nuts, producing 52% of exports, followed by Brazil at 42% and Peru at 6% (Guariguata et al. 2017).

Success factors and potential for the harvesting of Brazil nut

- In Bolivia, investments have been made in processing industries, and internal quality regulations have secured access for Bolivian Brazil nuts in global markets (Guariguata et al. 2017). The Government of Bolivia and its Brazil-nut producers reacted quickly and efficiently when the European Union implemented stricter aflatoxins standards in 1999. Among the measures put in place was a mandate to verify each export shipment of Brazil nuts and the organization of an independent association to test the shipments and invest in manufacturing practices (Coslovsky 2014).
- Tens of thousands of rural households harvest Brazil nut in Bolivia. Most of the harvest is conducted by nut gatherers, who live close to areas that are rich in Brazil-nut trees.
- In recent years, there has been a shift in property rights in Bolivia, Brazil and Peru that has favoured Brazil-nut gatherer households, with large areas of Brazil-nut-rich forests titled to local communities or indigenous territories. In the department of Pando in Bolivia, for example, over 2 million ha of forest were under local control by 2010 (Guariguata et al. 2017).

- Secure property rights provide nut gatherers in Bolivia with more economic scope because they don't need to pay fees to estate owners and can negotiate directly with intermediaries (Guariguata et al. 2017).
- The independence of local nut gatherers has increased through the creation of cooperatives and the establishment of local processing plants, enabling nut gatherers to better defend their property rights and increase their profits. A successful approach for such cooperatives in Bolivia was to contract third-party processing plants (Guariguata et al. 2017). This enabled the cooperatives to sell their products directly to international buyers and obtain higher prices without the risks associated with managing processing plants (Guariguata et al. 2017).
- Brazil-nut production can be comanaged with timber harvesting (of other species) and other activities, such as ecotourism. In Peru, Brazil-nut production was found to be unaffected by a low-intensity timber harvesting regime (Rockwell et al. 2015). Traditional Brazil-nut gatherers often lack technical knowledge on timber harvesting, however, which increases the risk that they will damage Brazil-nut trees when logging (Cronkleton et al. 2012). This problem can be addressed through training in low-impact logging practices.

Factors for negative outcomes and challenges in the harvesting of Brazil nut

- In Brazil, a lack of processing facilities and infrastructure for storage and transportation led to a production decline. Additionally, the local industry was unable to meet the requirements of European Union quality standards that came into force in 1999 and it therefore lost access to this important market (Guariguata et al. 2017).
- Brazil-nut trees require a forest environment to grow and produce fruits (Guariguata et al. 2017). Deforestation due to mining, cattle ranching and the construction of roads and hydroelectricity plants led to a decline in Brazil-nut-rich areas. Outside forests, the habitual burning of pastures kills Brazil-nut seedings, and deforestation hinders cross-pollination because of the large gaps between isolated trees in deforested areas (Shanley et al. 2011).
- Identifying and addressing local drivers of deforestation through appropriate policy and practical measures will be crucial for maintaining the Brazil-nut resource (Guariguata et al. 2017).
- In Brazil, nut gatherers often feel compelled by economic pressures to immediately sell their products to intermediaries at relatively low prices rather than delaying sales and selling through cooperatives at higher prices (Tomasi 2016).
- Hierarchical relationships still exist between gatherers, local intermediaries, regional purchasers and the processing sector. Gatherers often receive at least part of their payment before delivering their products as a way of financing production. If the gatherers are unable to collect the expected quantity of nuts, however, this practice can put them into debt (Tomasi 2016). Moreover, debts incurred in previous harvesting seasons can trigger overharvesting in subsequent seasons and hamper the bargaining power of gatherers (Tomasi 2016).

Rattan (*Calamus* and *Daemonorops* species)

Common names: rattan, rotan

Present in: humid tropical zones of Africa, Asia, Australasia and the Pacific

Harvesting season: dependent on the maturity of the plant; cycles of 3–4 years

Harvesting yields: 20–25 kg/stem

Main uses: construction, furniture and baskets

Substitute: bamboo

Tree density in the forest: 30 canes/ha

Harvesting: mature canes are cut at least 10 cm above the ground and removed from the canopy by dragging

Processing: canes are cut into sections and then cleaned, bleached and dried

Rattan species are spiny climbing palms, mainly in the family Arecaceae and the subfamily Calamoideae. Of the approximately 600 rattan species, about 400 belong to the genus *Calamus* (Campbell et al. 2017). Only six species are used commercially: *Calamus dienpenhor*, *C. inopsi*, *C. manan*, *C. ornatus*, *C. scipionum* and *C. zellingerii* (Myers 2015). Rattans are abundant in humid tropical areas of Africa, Asia, Australasia and the Pacific; they generally grow best in well-drained soils and in moderate-to-high light conditions (Campbell et al. 2017).

The stems (i.e. canes without the leaves) are the main part of the plant used commercially. They are processed into furniture and also used in construction (Sunderland 2000). Rattans contribute to local communities in other ways, too—for example, the fruits and palm hearts of some species (e.g. *C. deerratus*) are edible and the leaves and roots are used medicinally (e.g. those of *Eremospatha macrocarpa* are used in the treatment of syphilis; Sunderland 2000). Rattan is harvested when the plant is mature, usually at 5–6 years of age but up to 15 years of age for large-diameter canes. Each stem yields approximately 20–25 kg (Siebert 2000; Meijaard et. al 2014). Most traded cane originates in Indonesia, Myanmar and Viet Nam and is mainly collected from the wild (Sunderland 2000). In Indonesia, rattan is produced commercially in about 11.5 million ha of natural forests and 50 000 ha of planted areas (Caroko undated). Indonesia produced 27 000 tonnes of rattan in 2013, which was about 80% of the raw material used in rattan products worldwide (Harbi et al. 2018). China and European countries comprise the main rattan importers (Caroko undated).

Rattan in secondary forest in the Philippines.
Photo © Yan Yu/ITTO

Success factors and potential for the harvesting of rattan

- By the end of the 1990s, rattan had come to be viewed as an "ideal" NTFP because it is easy to produce and international demand and prices were high. In 2004, the market for unprocessed and semi-processed rattan products was valued at USD 65 million and that for processed rattan products such as baskets and chairs was worth USD 892 million, with products traded globally (Meijaard et al. 2014).
- Only about 50 species of rattan are commercialized today, and there is considerable potential to promote many currently uncommercialized species (Caroko undated).
- Rattan products are lightweight, durable and flexible. Rattan is used mainly for furniture and construction in its unsplit form and for mats and baskets when split (Meijaard et al. 2014).
- Rattan became increasingly important commercially in Indonesia in the 1960s with the motorization of river transportation; the export value grew by more than 200% between 1968 and 1977 (Meijaard et al. 2014). Indonesian farmers profited from this rattan boom, accounting for up to 90% of the world market (Meijaard et al. 2014).
- Rattan is an especially important source of income for young men unable to engage in rice or cash-crop farming. In 1999, half of households in Central Sulawesi reported that rattan was their most important income source (Siebert 2000).

- Rattan is harvested almost entirely in natural forests and thus can constitute a forest management system in itself. Managed forests for rattan maintain the tree density and species diversity of natural forests, although generally with a lower basal area (Meijaard et al. 2014).

Factors for negative outcomes and challenges in the harvesting of rattan

- Rattan is harvested manually by local people. The work is labour-intensive and requires extended periods away from home; thus, young single men tend to be more involved than women and married men in rattan harvesting in the wild (Siebert 2000).
- In Indonesia, powerful furniture-producing organizations such as the Indonesian Furniture Industry and Handicraft Association have lobbied strongly for export bans on rattan to support local manufacturing structures. Various governmental interventions in the form of export bans for unprocessed and semi-finished rattan, imposed since the 1970s (most recently in 2011), have led to both local oversupply and declining prices (Meijaard et al. 2014).
- Because of the low price of rattan today, the importance of this NTFP as an income source in Indonesia has declined. The price of unprocessed rattan was USD 0.69 per kg in the 1980s, but it had crashed to USD 0.15 per kg by 2010. Livelihood surveys conducted in 2011 found that farmers preferred to invest in more-profitable rubber or palm-oil production (Meijaard et al. 2014).
- Rattan stocks in Southeast Asia declined rapidly from the 1970s due to overharvesting and the conversion of forest for rubber and palm-oil production (Siebert 2000). Combined with a lack of support from the state, many local rattan enterprises (that in some cases had been operating for generations) were lost (Siebert 2000).
- Interviews with local operators in Indonesia revealed illegal practices in the rattan industry, including by cartels to control prices and limit the availability of information on trading volumes. Although there is no proof that such cartels exist, it could explain why farm-gate prices have remained low in recent years, even when rattan supply was low (Meijaard et al. 2014).
- Improving the market for rattan will require accurate data on the existing trade and an understanding of the needs of the domestic industry and the potential of export markets. Price cartels, if they exist, will need to be dismantled to enable farm-gate prices to rise, and sustainable management practices will need to be put in place (Meijaard et al. 2014).

Rubber (*Hevea* species)

Common names: rubber, seringueira

Present in: Amazon Basin

Harvesting season: in Brazil, the dry season in Acre and the rainy season in Pará

Harvesting yields: 1–3 litres per tree per year

Main uses: a wide range of industrial uses, such as in vehicle tyres and medical supplies

Substitute: synthetic rubber

Tree density in the forest: 1–1.5 trees per ha

Harvesting practices: latex is collected by slicing a groove into the bark of tree trunks using special tapping knives

Rubber-tapping in the Antimari State Forest, Acre, Brazil. Photo: © ITTO/R. Guevara

Natural rubber is obtained from the latex harvested from *Hevea* species. The main species is *H. brasiliensis*, a tree native to the Amazon Basin (Heng and Joo 2017; Gomes et al. 2012). Latex is collected by slicing grooves into the bark of trunks using special tapping knives (Heng and Joo 2017). Latex collection is possible only from trees in the wild at an age of about 30 years or when the tree has reached a thickness of 15 cm (Mercur 2016); planted rubber-tree clones, on the other hand, are suitable for latex harvesting after seven years (Mercur 2016). *Hevea brasiliensis* is a hyperdominant tree species in the Amazon, with trees occurring at densities of 1–1.5 trees per ha (Schroth et al. 2003); latex production is estimated at 1–3 litres per tree per year (Jaramillo-Giraldo et al. 2017). Natural rubber has thousands of applications, but most of the large global demand today is met by plantations in Asian countries (Jaramillo-Giraldo et al. 2017), which were established in the early 1900s with seeds of *H. brasiliensis* imported from Brazil (Schroth et al. 2003).

The first Amazonian rubber boom occurred in 1850–1920, mainly because of the discovery (by Charles Goodyear) of a process for curing rubber, which greatly improved rubber quality and widened its uses. The rubber boom enabled the development of the Amazon region: latex exports from the region increased from 156 tonnes in 1830 to 2673 tonnes in 1860 (Sousa undated). The rubber market crashed in 1910, however, when rubber from Southeast Asian plantations came on stream (Schroth et al. 2003; Schor and Marinho 2013). The trade of rubber from the Amazon increased again in 1942–1945 during the Second World War when Japan blocked the supply of goods from Asia to the United States of America (Jaramillo-Giraldo et al. 2017; Palitot 2015). During the Amazon's second rubber boom in the 1940s, more than 100 000 workers migrated from northeastern Brazil to the Amazon to work as rubber tappers, and many stayed after production declined (Palitot 2015). Discontent arose in the 1970s against working conditions, which were characterized by indebtedness, a harsh working environment and land disputes. This led to the formation of unions and the establishment of extractive reserves, which are defined areas for the collection of NTFPs (Campos undated). Today, a pro-rubber-tapping movement, and a strong sense of identification among natural-forest rubber tappers, persist in the Amazon (Jaramillo-Giraldo et al. 2017), particularly in Acre, Brazil.

Worldwide, the production of natural and synthetic rubber combined amounted to about 28.8 million tonnes in 2019, of which 13.7 million tonnes was from natural rubber (International Rubber Study Group undated). About 335 000 tonnes of production was derived from harvesting wild rubber in the Amazon. The bulk of natural rubber production comes from plantations, with Thailand, Indonesia and Malaysia by far the leading producers, at 12.3 million tonnes in 2019 (International Rubber Study Group undated).

Natural latex is usually sold in a solid state, which is formed through the addition of an acid, usually the sap of *Ficus dendrocida* (Heng and Joo 2017). In July 2020, the market price of rubber in Brazil was BRL 12.2 (USD 2.2) per kg (Index Mundi undated).

Rubber-tapping in the Antimari State Forest, Acre, Brazil. © R. Guevara/ITTO

Success factors and potential for rubber harvesting

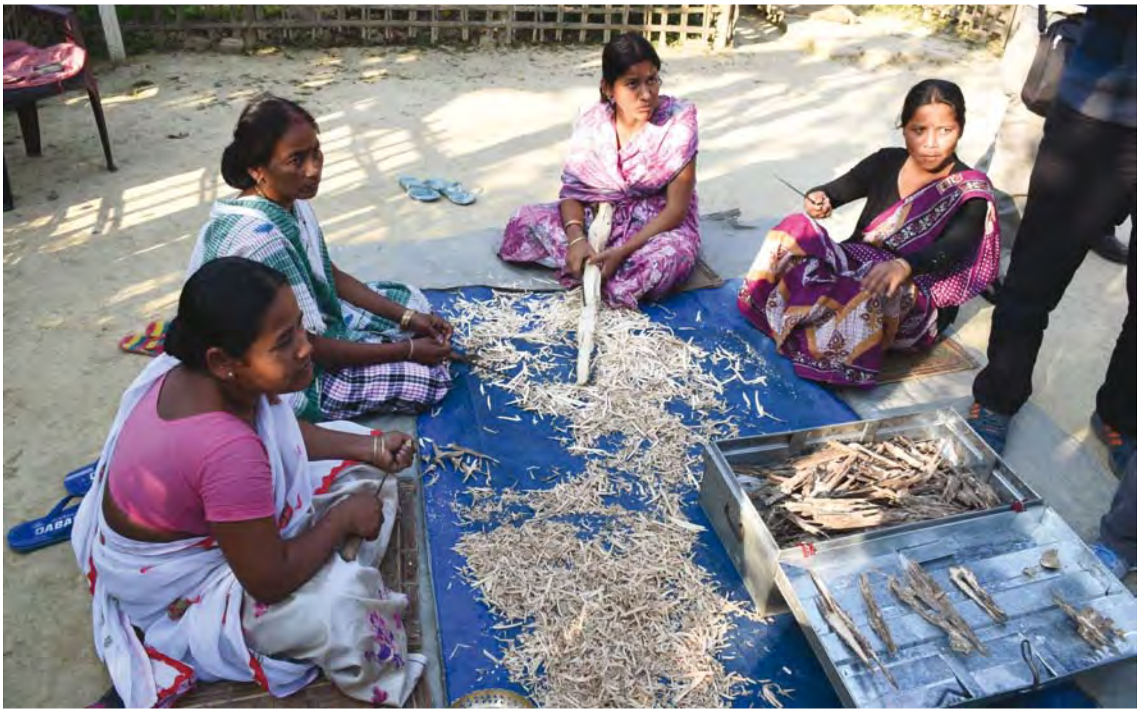
- Global rubber demand is high—about 40 000 products, mainly in the medical and pneumatics industries, contain specific uses for natural rubber (Reis 2015).
- In Acre, Brazil, there are well-established rubber production chains supported by public institutions with the aim of preventing the expansion of cattle ranching. Rubber tappers receive public subsidies in addition to revenues from sales to ensure a minimum wage. In 2012, the subsidies were in the range of USD 1.75–4.00 per kg of rubber (Jaramillo-Giraldo et al. 2017).
- To encourage sustainable rubber extraction in the Amazon, it is necessary to develop niche markets, for example by encouraging the automobile industry to buy tyres made of rubber from natural forests. Other possibilities are investments in new technologies to use the lubricant properties of *Hevea* species and the wastes generated in the pneumatics sector in paving (Jaramillo-Giraldo et al. 2017).
- An example of the innovative use of natural rubber is provided by the Brazilian company Mercur, which makes products such as erasers and hot-water bottles using natural rubber (Mercur 2016). Nevertheless, only about 1% of the processed rubber it obtains is from natural forest (from a cooperative in Pará) (Mercur undated).
- Rubber trees were domesticated to increase the efficiency of rubber production in the face of strong demand (Lieberei 2007). In Brazil, the government has supported the establishment of agroforestry systems using disease-resistant clones of *Hevea* species to restore degraded areas and contribute to the local economy (Jaramillo-Giraldo et al. 2017).

Factors for negative outcomes and challenges in the harvesting of rubber

- Rubber collecting is a labour-intensive, highly skilled activity that requires training (Reis 2015).
- The development of *Hevea* plantations in South America, and the natural-forest resource, have been affected by a native fungus, South American leaf blight (*Microcyclus ulei*) (Jaramillo-Giraldo et al. 2017; Lieberei 2007), but the disease is absent in Southeast Asia (Lieberei 2007). This has made it difficult for natural rubber in South America to compete in the international market (Jaramillo-Giraldo et al. 2017).
- Asian rubber plantations are mainly homogenous plantations established on land previously cleared of natural forests; in the Amazon, natural rubber is mostly produced in natural forests and agroforestry systems. The latter may produce rubber less efficiently (at a higher cost), although rubber production provides an incentive for SFM (Jaramillo-Giraldo et al. 2017).
- Rubber-tapping is much more efficient in rubber plantations compared with natural forest: a rubber tapper might harvest 500–600 kg per year in natural forest but up to 20 tonnes per year in plantations (Jaramillo-Giraldo et al. 2017).
- Even with government support in the form of subsidies, rubber collection in natural forests in Brazil delivers only modest incomes to rubber tappers (USD 1–8 per ha per year), which is considerably less than the average income from extensive cattle ranching (USD 50 per ha per year) (Jaramillo-Giraldo et al. 2017).

3 CASE STUDIES OF PROMISING NON-TIMBER FOREST PRODUCTS

The previous chapter described three NTFPs with established markets. In the case of rubber, the large part of the production is from planted trees; in the case of Brazil nut, on the other hand, the species is frustratingly difficult to domesticate and cultivate and thus remains largely a typical NTFP that needs to be grown and harvested in natural forests. In this chapter, we focus on six promising NTFPs that still grow in tropical forests—two each from tropical Africa (allanblackia and safou), Southeast Asia (agarwood and damar resin), and the Amazon (açaí and wild cocoa)—and for which the potential is yet to be fully realized. For all six NTFPs, we anticipate large global market expansion in the next decade. In some cases, the NTFP has largely been domesticated and enriched in forests or grown in agroforestry systems; this is the case for cocoa, which also grows wild—and is harvested—in natural tropical forests. Some NTFPs have natural or synthetic substitutes: allanblackia butter, for example, is similar to shea butter, and damar resin can be substituted by synthetic resins. In other cases, the NTFPs are unique, novel and have no comparable substitute. For example, safou, a savoury fruit in West and Central Africa, has a unique taste and texture. This fruit is unknown outside the range countries and their diaspora but, as the story of avocado in the 1960s shows, aggressive marketing could expand its popularity. In all the case studies presented here, more information is needed on multiple-use forest management to produce timber and NTFPs while ensuring economic viability, social equity and forest conservation.



Extracting agarwood after harvest, India. Photo: © Assam Agarwood Association

Allanblackia (*Allanblackia* species)

Common names: allanblackia, msambu, mkimbo, mkani, mkany, mkanyi, obiobo obo, vegetable tallow tree, lacewood, ouotéra

Present in: Cameroon, Ghana, Nigeria and the United Republic of Tanzania

Harvesting season: November–March (Ghana)

Harvesting yields: 10 kg oil/tree per year; 6 fruits = 3 kg of seeds = 1 kg of oil

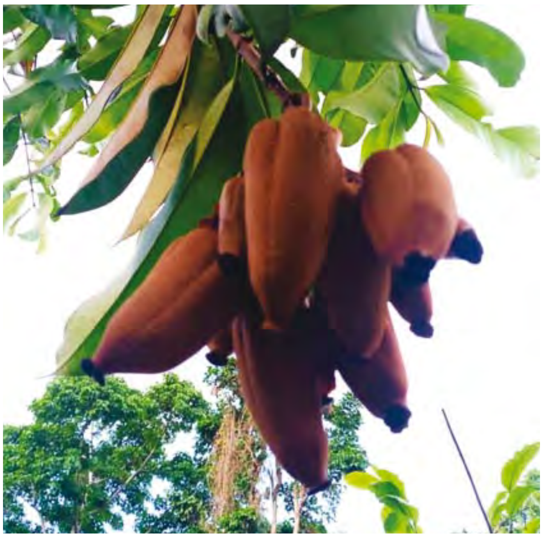
Main use: edible oil

Substitutes: palm oil, shea butter, cocoa butter

Tree density in the forest: 1.5–4 trees/ha

Harvesting practices: mature fruits drop to the ground, where they are collected

Handling: the seeds are extracted from the fruit and dried and crushed. The resultant mass is mixed with water and boiled until the fat separates and the oil can be collected



Allanblackia fruit, Ghana. Photo: © Jonathan Dabo

Allanblackia species (allanblackia) are trees native to tropical Africa; they grow in evergreen forests from Cameroon to the Democratic Republic of the Congo and in the tropical montane forests of Uganda and the United Republic of Tanzania (Allanblackia Partners undated). Allanblackia is commonly found on slopes and acid soils (Orwa and Oyen 2007); it is a medium-sized tree that attains heights of about 30 m and a dbh of 80 cm.

Vegetable oil can be extracted from the seeds, mainly from the following three species: *A. floribunda*, found in Angola, the Central African Republic, eastern Democratic Republic of the Congo, Nigeria and Uganda; *A. stuhlmannii*, found in the United Republic of Tanzania; and *A. parviflora*, found in Ghana, Guinea and Sierra Leone (Anonymous 2016; Tchinmegni 2016). Allanblackia oil is solid at room temperature and has high stearic acid (52–58%) and oleic acid (39–45%) content (Crockett 2015). The oil has great potential in the food industry—unlike palmitic acid, stearic acid does not affect blood cholesterol (Crockett 2015) and its use could therefore help in the prevention of cardiovascular diseases (Tchinmegni 2016; Crockett 2015). Local people also use allanblackia bark to treat ulcers and rashes (Tchinmegni 2016; Crockett 2015).

Conflicts over use between timber and non-timber forest products

Allanblackia wood has been used traditionally as fuel and for house construction. A study in Nigeria showed that the uncontrolled harvesting of allanblackia timber almost led to the local extinction of the species (Allanblackia Project 2016; O Nuga et al. 2012). In international markets, however, allanblackia timber is viewed as a lesser-used species. Allanblackia oil was already being traded internationally in the colonial period in the late nineteenth century, and it was used as a substitute for cocoa butter in the First World War (Crockett 2015). Currently, the oil of allanblackia is more commercially important than its timber because of its potential to substitute for palm oil (Allanblackia Project 2016). Thus, although there might be local conflicts over use due to traditional practices, the larger-scale commercialization of allanblackia is focused on oil production, and conflict with timber production is negligible.

In collaboration with local farmers in Ghana, Nigeria and the United Republic of Tanzania, IUCN and Unilever developed guidelines on best practice in the sustainable wild harvesting of allanblackia designed to enable the conservation and use of the species for its valuable oil (Amanor et al. 2003). The guidelines include detailed recommendations on how to sustain both biodiversity in the landscape and local socioeconomic values.

Factors for negative outcomes in the harvesting of allanblackia oil

In Ghana, allanblackia oil is processed and consumed by households. Local markets are not well developed, however, and, for a long time, prices were too low to encourage farmers to harvest seeds outside their farmlands (Amanor et al. 2006).

The large-scale commercialization of allanblackia oil began in 2002, when Unilever developed a margarine based on the oil, which has ideal consistency for use as a bread spread. Market development for a traditional food product like allanblackia oil in international markets (e.g. in Europe) involves lengthy research and approval processes. For this reason, small companies often lack the resources to undertake such development.

The mass production of allanblackia oil by Unilever was supported by the Novella project, which began in 2002 in Ghana, Nigeria and the United Republic of Tanzania and involved a partnership of more than 30 local and international organizations, including FORM international, IUCN, Unilever, the Union for Ethical Bio Trade and the World Agroforestry Centre. The aim of the project was to alleviate poverty and prevent deforestation by commercializing allanblackia NTFPs (Anonymous 2016). The initial strategy was to develop a supply chain based on wild harvesting. The World Agroforestry Centre estimated a demand of more than 100 000 tonnes per year for allanblackia oil, however, and found that meeting this from wild-grown trees would be difficult and environmentally damaging (Allanblackia Project 2016). Wild allanblackia trees start producing fruits at 7–10 years of age and reach peak yield at 20–30 years (Anonymous 2016; Crockett 2015; Jamnadass et al. 2014). The abundance of allanblackia is low in natural forests (1.5–4 trees per ha), and the labour requirement for harvesting is high because the trees are widely scattered and only female trees bear fruit. Moreover, high demand was likely to lead to unsustainable harvesting and overexploitation, affecting future production and biodiversity conservation (Ofori et al. 2013). High demand could also increase harvesting from the wrong species, leading to uncertainties about the content of the oil (nine species of allanblackia are known but only three are considered safe for commercialization) (Crockett 2015). Therefore, the harvesting of large quantities of allanblackia oil in the wild was considered unrealistic and the Novella project encouraged domestication (Anonymous 2016; Ofori et al. 2013).

About 150 tonnes of allanblackia oil was produced in 2012 in the United Republic of Tanzania, where farmland harvesting is more common and plantations of selected trees were already established. Ghana and Nigeria, on the other hand, where most of the harvesting was in the wild, produced only 40 and 20 tonnes of oil, respectively, in the same year (Anonymous 2016). Thus, only about 210 tonnes of oil was produced in 2012 in the three countries combined, which was insufficient for large-scale industrial development; further domestication is required to generate sufficient quantities.

Management possibilities and potential

Allanblackia is a well-known tree among local people, and it is valued for its economic potential and as a shade tree for certain crops, such as cocoa (Amanor 2006). Even though seeds often obtain only low prices, 75% of local people surveyed in Ghana in 2006 reported that allanblackia was one of several NTFPs they harvested and sold to supplement their incomes (Amanor 2006). Most of this harvesting was performed on farmers' own farms because the distance to forest reserves was too far, although considerable harvesting also took place in forest reserves in communities close to those reserves (Amanor 2006).

Although the Novella project focused on domestication and agroforestry systems in the cultivation of allanblackia because of high demand, the wild collection of seeds still plays an important role. The organized harvesting of allanblackia seeds according to the IUCN/Unilever guidelines (Amanor et al. 2003) is an example of best practice in sustainable NTFP harvesting.

The Novella project used a participatory approach to ensure that local farmers benefit over time (Jamnadass et al. 2014). Tasks were divided among the various stakeholders involved in allanblackia domestication and harvesting. For example, local companies such as Novel Development Ghana Ltd, which processes allanblackia seeds into oil, provided local support and assisted farmers in their planting activities. Additionally, non-governmental organizations, community groups and national institutions created rural resource centres to provide farmers with information on allanblackia and to experiment with different domestication techniques (Jamnadass et al. 2014; Ofori et al. 2013).

Much has been learned through the Novella project, but smaller-scale approaches are also feasible. An alternative to the market chains developed through the Novella project is the establishment of cooperatives to refine the seeds for local markets and niche products. The United Kingdom-based company Akoma established cooperatives in Ghana that harvest and refine products from NTFPs, including allanblackia butter from wild-collected allanblackia seeds. The products are then sold through an online store (Akoma undated). Ninety-eight percent of allanblackia seed in Ghana is sold to the Novella project and only 2% is sold via local oil processors; no independent data are available on local market prices independent of the Novella project (Amanor 2006).

Another option to foster the harvesting of allanblackia seeds in natural forests in the future would be a strategy of enrichment planting. The Novella project (mainly the World Agroforestry Centre) has developed methods for propagating allanblackia seedlings in nurseries as well as for gene conservation and integration into agroforestry systems (Jamnadass et al. 2014). This knowledge could be deployed to enrich certain natural forests with allanblackia and thereby address the low abundance of the species. A study in the United Republic of Tanzania showed that enrichment plantings in the Amani Nature Reserve using seeds of *Allanblackia stuhlmannii* exhibited high germination and establishment rates (Seltzer et al. 2015). Enrichment could be achieved by encouraging seed collectors to plant a seed for every fruit harvested (Seltzer et al. 2015).

No data are available on the co-harvesting of allanblackia seeds and timber harvesting in natural forests. In one study in Ghana, allanblackia trees were found to be present in logged forests at densities of five trees (dbh > 10 cm) per ha. This suggests that, with appropriate management plans, the combined harvesting of timber and allanblackia seeds might be possible (Samuel 2014).

Market evaluation of the commercialization of allanblackia seeds and oil

Mature allanblackia trees produce about 60 fruits and 30 kg of seeds per year, which yields about 10 kg of oil (Allanblackia Partners undated). Harvesters collect mature fruits in the forest that have fallen to the ground and extract the seeds from the fruits. Companies involved in the Novella project buy most of the seeds from harvesters; in 2011, they paid USD 0.25 per kg of seeds (Ofori et al. 2013). No data are available on local market prices. According to gatherers in Ghana, the price is lower than for other forest products, such as kola nuts (*Cola nitida*) and bush mango (*Irvingia gabonensis*). A 2015 study in Benin reported that kola nuts were obtaining a price of EUR 1.98 (USD 2.15) per kg in local markets (Dah-Nouvlessounon et al. 2015). In addition to the usual challenges concerning the harvesting of forest products, such as the often long distances involved, allanblackia pods are bulky and must be further processed at home, hindering the scaling up of production. In Ghana in 2006, for example, most farmers collected 11–20 pods per day and 50–100 pods per year (Amanor 2006). Assuming 0.5 kg of seeds per pod, this quantity would have generated an annual income of only USD 6–12.

The Novella project companies mostly undertake the further processing of allanblackia seeds, which involves drying and crushing the seeds to produce a mass that is then mixed with water and boiled until the fat separates and the oil can be collected. Unilever conducts further product development at its own cost (Jamnadass et al. 2014). The end product, a margarine, retails in Swedish supermarkets for about USD 3 per 400 g pack (Matspar undated).

Conclusions

- In the recent large-scale commercialization of allanblackia, conflicts of use between the NTFP and timber harvesting were negligible because the oil has significantly higher value than the timber, for which there is no international market. Nevertheless, local people have traditionally harvested the timber for woodfuel and house construction, which, in some areas, has almost caused local extinctions. This shows the necessity for clear guidelines on sustainable harvesting to ensure the persistence of allanblackia trees.
- Local markets for allanblackia seeds are not well developed, and collectors and processors consider that prices are low. A fixed, strong demand was created with the establishment of the Novella project. Because the tree is low in abundance and productivity, domestication has been pursued.
- Nevertheless, the Novella project still involves harvesting in the wild, and detailed guidelines have been developed for sustainable harvesting and participatory approaches with farmers, who have received support and training. This assistance has fostered the sustainable collection of allanblackia seeds by local people.
- Possible approaches to enable the sustainable harvesting of allanblackia seeds on a small scale that would not necessarily require domestication-based production would be:
  - the harvesting and processing of allanblackia seeds in cooperatives for local markets and niche products; for example, the United Kingdom’s Akoma is selling its allanblackia products online; and
  - enrichment planting, shown to be successful in a study in the United Republic of Tanzania, which would address the low natural abundance of allanblackia in forests.
- As a common understorey tree in lowland moist forests in the Congo Basin, allanblackia can potentially be managed as an NTFP in tropical production forest, but definitive management experience is lacking.

Safou (*Dacryodes edulis*)

Common name: African plum, native pear, bush butter tree, African pear, safou, safoutier, prunier, atanga, nsafu

Present in: West and Central Africa

Harvesting season: May–October

Harvesting yields: 223–335 kg per tree per year

Main uses: edible fruits and oil; the bark, leaves and resin are used to treat malaria, fever and skin diseases

Substitutes: *Dacryodes buettneri* and *Dacryodes klaineana*

Tree density in the forest: 0.2–0.4 trees per ha

Harvesting practice: climbing the tree and/or knocking the fruit down with a long pole

Handling: seeds are removed and the fruit boiled and dried

Safou fruits with plantain, Cameroon.
Photo: © S. Hauser/IITA, Ibadan, Nigeria

Dacryodes species belong to the family Burseraseae (Tee et al. 2014). The word *dacryodes* originates from the Greek *dakrun*, which means "tear", reflecting the fact that the tree produces resin when its bark is injured (Tee et al. 2014). There are approximately 70 species of *Dacryodes* in the tropical forests of Africa, America and Southeast Asia (Tee et al. 2014).

Dacryodes edulis is a dioecious evergreen tree that grows in non-flooded forest in the humid tropics of Africa (Orwa et al. 2010) in a range encompassing the Atlantic coast from Sierra Leone to Angola and Central Africa (Verheij 2002). This shade-tolerant tree grows in a wide range of soils but prefers ferralitic and volcanic soils (Orwa et al. 2010). Trees grow to a height of up to 40 m in the forest but only to 10–12 m in plantations (Orwa et al. 2010). The fruit (safou) is large and cylindrical, and it turns from pink-red when unripe to blue-black when ripe (Tee et al. 2014). Safou is 4–12 cm long and 3–6 cm in diameter and has a high content of protein, fat and vitamins (Youmbi et al. 1989; Anegbeh et al. 2005).

Safou has considerable local market value and is highly valued by local people; it is one of the most consumed fruits in the Congo Basin (Rimlinger et al. 2019). It can be consumed raw but is usually boiled or cooked to soften the pulp (Orwa et al. 2010; Rimlinger et al. 2019; Tee et al. 2014). The fruit is commonly boiled in salted water in Nigeria and roasted in Cameroon (Anegbeh et al. 2005). To preserve safou, the seed is removed and the pulp boiled and dried in the sun (Verheij 2002). Given its importance in local diets, *D. edulis* is widely cultivated and has been in a process of domestication (Leakey et al. 2004). In addition to the use of its fruit as food, the tree produces a resin that can be applied to treat wounds and other skin diseases; the leaves are used in the treatment of dysentery and the bark is applied against malaria and fever (Verheij 2002; Tee et al. 2014). The oil yielded from the fruit is used in the cosmetics and food industries (Ajibesin 2011).

The fruit produced by *D. buettneri* resembles that of *D. edulis* but is slightly smaller (Fern 2019); it is also collected in forests as a locally important NTFP (Iponga et al. 2017). The fruit of *D. buettneri* is boiled in water for edible uses and the resin is applied to ulcers and abscesses. The bark is used in the treatment of burns (Fern 2019).

Conflict of use

Even though the timber of *D. edulis* is supposedly of high quality comparable with African mahogany (Verheij 2002), it is mainly used locally for axe handles and in carpentry and is not widely traded commercially (Burkill 1985).

The timber of *D. buettneri* is more commonly used commercially—as plywood and sawnwood for construction, furniture and parquetry (Todou and Doumenge 2008). The export volume of *D. buettneri* timber decreased from 160 000 m^3 per year in the 1990s to 20 000–30 000 m^3 per year in 2005; nevertheless, the species was still the ninth-most exported timber in Gabon in 2005 and was also widely traded domestically (Todou and Doumenge 2008).

In summary, there is a potential conflict of use between the harvesting of *D. buettneri* for timber and NTFPs. In the case of *D. edulis*, the potential for conflict of use seems minor because the NTFPs are highly valued locally and viewed as more important than the timber, which is not widely marketed. Nevertheless, there is potential for widespread commercialization of the timber because of its similarity to African mahogany (*Khaya* species), which sells for up to USD 450 per m^3 (ITTO 2018).

Heavy logging could cause the depletion of *Dacroydes* species in natural forests, and approaches are needed, therefore, to ensure the sustainability of NTFP harvesting. These might include spatially separated management for timber and NTFPs; or a timber harvesting regime based on tree size (the highest yields of NTFPs are often observed in trees of intermediate size rather than large trees) (Guariguata et al. 2011). In situations where the value of the NTFPs is higher than that of the timber, harvest quotas or total legal protection from logging may be used, as is the case for Brazil-nut trees in Bolivia, Brazil and Peru (Guariguata et al. 2011).

Factors for negative outcomes in the harvesting of Dacryodes

Dacryodes edulis trees occur in low densities in the wild (Sunderland and Ndoye 2004). A density of 0.2–0.4 trees per ha has been observed in Nigeria, which is considerably less than the density of other locally important fruit trees, such as *Irvingia* species (Sunderland and Ndoye 2004). The low natural density has prompted the long-term cultivation of *D. edulis* in agroforestry systems and homegardens (Schreckenberg et al. 2002). A study in Nigeria estimated that 95% of harvested fruit was produced in agroforestry plantings or on farms, where tree densities exceed 3 trees per ha (Sunderland and Ndoye 2004). In Cameroon, the fruit produced in natural forests is smaller than that grown on farms, and local people are not interested in collecting it in the wild (Ndindeng et al. 2012). Farmers plant the trees to provide shade in cocoa farms, where it is the most common fruit tree (Schreckenberg et al. 2002). Thus, *D. edulis* has been described as an NTFP in the process of domestication, although it is not yet an established farm crop (Awono et al. 2002).

Safou is quickly perishable, lasting only 2–3 days (Ndindeng et al. 2012). It is estimated that up to half the harvest is lost during the fruiting season due to soft rot (Schreckenberg et al. 2002), which means it is difficult for farmers to store and transport the fruit and often forces them to sell to traders instead of taking the harvest to market themselves (Schreckenberg et al. 2002). Efforts are being made to increase the durability of the fruit through processing and genetic selection, which could eventually help in transporting it over longer distances and enable farmers to sell over a longer period than the current four months of the harvesting season (Simons and Leakey 2004).

Management possibilities and potential

Fruit pulp of *D. edulis* contains high levels of oil—— 30–60% of the dry matter content, on average, and as high as 70% (Ajibesin 2011). The oil is rich in palmitic acid (9–60%), oleic acid (20–50%) and linoleic acid (15–35%), comparable with the fatty acid composition of avocado (Ajibesin 2011; Ikhuoria and Maliki 2007). The seeds of *D. edulis* have the same fatty acid composition as the fruit pulp and an oil content of up to 70%, which is considerably higher than for other seed, such as palm kernel (40%) and soybean (20%) (Isiuku et al. 2008). For this reason, the healthy and nutritious fruit and seeds of *D. edulis* are very popular among local people, and their importance is enhanced by their availability in the "hungry season" at the end of the dry season and beginning of the rainy season, when local products such as cocoyam and rice are not yet mature (Sunderland and Ndoye 2004; Falconer 1990).

In Cameroon, local farmers cultivate *D. edulis* in remaining patches of secondary forest, along with other useful tree species such as pygeum (*Prunus africana*) and okok (*Gnetum africanum*) (Jaza Folefack et al. 2019). These secondary forest patches have remained stable in size over time, in contrast to areas of primary forest, which have largely been deforested (Jaza Folefack et al. 2019).

Dacryodes edulis is considered the most important tree species in many homegardens and agroforestry systems, accounting for 28–57% of all trees in agroforestry systems in Central Africa (Simons and Leakey 2004). Farms in Cameroon typically contain 20–200 *D. edulis* trees (Simons and Leakey 2004). In Central Africa, *D. edulis* is one of the most common edible intercrops in cocoa plantations, along with *Citrus sinensis*, *Citrus reticula*, *Mangifera indica* and *Persea americana* (Sonwa et al. 2014). In Cameroon, 91% of all cultivated *D. edulis* trees are in perennial crop plantations such as coffee and cocoa (Schreckenberg et al. 2002).

In the southern regions of Gabon, it was observed that *D. buettneri* was one of the most collected forest products in the region, along with odika (*Irvingia gabonensis*), termite mushrooms (*Termitomyces* species) and kola nut (*Coula edulis*) (Iponga et al. 2017). Although the average income per household generated from the collection of *D. buettneri* was estimated at about CFA 10 000 (USD 17), the majority of it was used for home consumption and only the surplus was sold for cash income (Iponga et al. 2017). The collection of NTFPs contributes a relatively small share of the income of the locals compared with agriculture, but it can be important, especially for poorer families, who generally rely more on income from NTFPs than do wealthier families (Iponga et al. 2017).

Market evaluation of commercialization

Dacryodes edulis produces 20–335 kg of fruit per tree year, with an annual yield of 7–10.5 tonnes per ha (Verheij 2002; Sunderland and Ndoye 2004). The volume of traded safou in Cameroon has been estimated at 11 000 tonnes per year at a value of USD 7.5 million, making it the third-most popular fruit crop in the region after plantain and kola (Awono et al. 2002; Ayuk et al. 1999a).

In Nigeria, the annual income of safou-producing families was USD 650 in 2002, which was higher than the national average income of USD 490, with 5% of the income generated by safou production (Sunderland and Ndoye 2004). On average, farmers received 75% of the market price paid to traders (Awono et al. 2002); 41% of production was sold and the rest remained for self-consumption (Ayuk et al. 1999a). Safou harvesting is labour-intensive, with an average of 50% of household members involved in the production process (Sunderland and Ndoye 2004). The harvesting and packaging of a 100-kg bag of safou requires about three person-days (Sunderland and Ndoye 2004). The further processing of the fruit, such as into oil, is rare (Sunderland and Ndoye 2004).

The market price is highly dependent on season. In Cameroon, the price for a bag of fruit peaks in December and is lowest in August (Awono et al. 2002). Belgium, France and the United Kingdom are the main importing countries, with immigrants from Central Africa the main consumers (Awono et al. 2002). Recent data on market prices are unavailable. In 1999, Europe imported 326 tonnes of safou at a value of USD 2 million (Awono et al. 2002). The average price of safou in that year was USD 7.5 per kg in Paris and USD 9 per kg in Brussels (Awono et al. 2002).

Conclusions

- *Safou* is very popular among local people in the Congo Basin because of its high oil content. It is particularly important in the “hungry season”.
- *Dacryodes edulis* is cultivated mainly in homegardens and as a shade tree in cocoa plantations. In Nigeria, only 5% of safou is harvested in forests, where the fruit is smaller than in plantations and tree density is low.
- *Dacryodes buettneri*, in contrast, is still mainly harvested in forests. In Gabon, its fruit is one of the most commonly collected NTFPs. Even though it makes a relatively small contribution to household income, the fruit provides important complementary income, especially for the very poor.
- Even though the timber of *Dacryodes edulis* is of high quality, comparable with African mahogany, the timber is used mainly for axe handles and carpentry and is not widely traded commercially. The timber of *D. buettneri* is more commonly traded, mainly for construction and furniture; it was ranked the ninth-most important timber for export in Gabon in 2005.
- The volume of traded safou in Cameroon was estimated at 11 000 tonnes in 2015, making it the third-most popular fruit crop after banana and kola.
- The value of safou production is in the range of USD 9–160 per farmer per year. On average, producers sell 41% of their production and use the rest for self-consumption; on average, they receive 75% of the market price paid to the traders.
- The main export markets for safou are Belgium, France and the United Kingdom, where immigrants from West and Central Africa are the main consumers.

Agarwood (*Aquilaria* and *Gyrinops* species)

Common names: wood of the gods, oud, gaharu, jinko, aloeswood, adlerholz

Present in: South and Southeast Asia

Harvesting season: year-round

Harvesting yields: 0.10–2.13 kg per tree

Main use: incense and for medical purposes; the oil is used as a perfume component

Substitutes: there are no natural analogues

Tree density in the forest: 2 trees per ha in non-inundated rainforests at low and medium elevations. Wild populations are endangered

Harvesting practices: in most cases, agarwood-producing trees are felled and cut open to harvest the resin. Alternative harvesting practices include tapping the tree and using a knife to cut out the agarwood without felling the tree

Handling: agarwood is exported in the form of wood chips or further processed into oils, incense and medicines

Species of the genus *Aquilaria* in the Thymelaeaceae family are the best-known of the agarwood-forming trees (Ali undated). Other genera that produce agarwood include *Gonystylus, Gyrinops* and *Phaleria* (Sampson and Page 2018). Agarwood is a dark-coloured, fragrant resin (Jensen 2009) produced by trees in reaction to external irritants (Sampson and Page 2018). The exact mechanism involved in the formation of agarwood is not fully understood, but it is conjectured that either a fungal infection or other wounding of the tree, or both together, trigger the production of agarwood (Akter et al. 2013). Agarwood is created in the trunk, branches and roots of trees, where it hardens over time and turns dark brown (unaffected wood in agarwood trees is pale) (Ali undated).

Agarwood species occur in South and Southeast Asia—from the foothills of the Himalayas in northern India to Indonesia, Papua New Guinea and the Philippines. It grows at low densities in primary and semi-evergreen forest (Jensen 2009) on a wide range of soils, including sandy soils; seedlings establish best in shade (Ali undated).

The harvesting of wild agarwood is destructive because it involves the felling of the tree (Jensen 2009; Faizal et al. 2016). Three species (*A. malaccensis*, *A. crassna* and *A. rostrata*) are listed as critically endangered on the IUCN Red List of Threatened Species, one (*A. microcarpa*) is listed as endangered

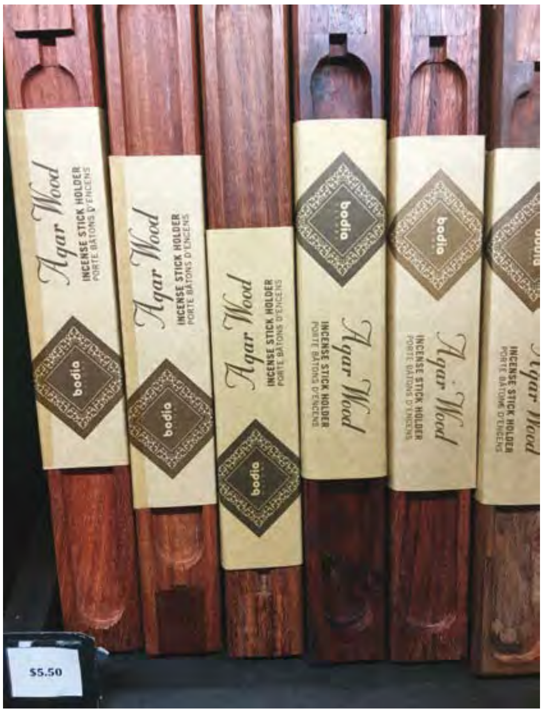
Agarwood harvest, India. Photo: © Assam Agarwood Association

and four (*A. sinensis, A. beccariana, A. filaria and A. hirta*) are listed as vulnerable, even though it is illegal in most countries to fell agarwood-producing species (Harvey-Brown 2018). Many of the remaining agarwood trees in the wild are in protected areas (Espinoza et al. 2014). *Aquilaria* species are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which imposes certain controls on the export of agarwood. ITTO and CITES have supported producer countries in meeting the requirements for the legal and sustainable trade of agarwood under CITES through the ITTO–CITES Programme (2007–2016) and the ongoing CITES Tree Species Programme (Box 9).

Agarwood is a complex combination of various volatile aromatic compounds, and the development of synthetic agarwood is complicated and expensive (Espinoza et al. 2014). Agarwood has been used for thousands of years; it is mentioned in the Old Testament, and it is used in the Islamic, Buddhist and Hindu traditions as incense (Sampson and Page 2018). Today, agarwood is one of the world's most expensive woods (Ali undated). Oil extracted from agarwood is used in perfumes and incense (Lim and Awang Anak 2010; Sampson and Page 2018). In China, agarwood is prescribed as a medicine against asthma and gastrointestinal disorders (Kanazawa 2016).

Conflict of use

Aquilaria and *Gyrinops* are not important timber species because their wood is light and has no resistance to decay. They have been used in paper production but, for centuries, their use in agarwood production has been more valuable (Blanchette et al. 2015). Thus, there is no conflict of use between agarwood and timber production.



Agarwood in a shop in Cambodia. © R. Carrillo/ITTO

Factors for negative outcomes in the harvesting of agarwood

The natural abundance of agarwood-producing trees is low, with recorded densities of *Aquilaria* species of less than 1.2 trees per ha in Indonesia (Soehartono and Newton 2001) and 0.8 trees per ha in Sarawak, Malaysia (Kanazawa 2016). High international demand has exhausted the resource in many producer countries (Lim and Awang Anak 2010; Kanazawa 2016). It has been estimated that 30 000–100 000 *Aquilaria* trees are harvested per year in Indonesia alone, out of an estimated total population of 2.6 million trees with a dbh greater than 10 cm (Soehartono and Newton 2001).

Agarwood trees are felled for harvesting and their stems and branches cut open to remove the agarwood (Soehartono and Newton 2001). Because there are no external signs that the tree contains agarwood, harvesters often fell *Aquilaria* trees that do not contain agarwood (Soehartono and Newton 2001). Given that only about 10% of *Aquilaria* produce agarwood, the indiscriminate felling of trees is a highly inefficient way of harvesting, leading to the rapid decline of natural populations (Liu et al. 2013; Soehartono and Newton 2001).

The quantity of agarwood obtained from a single tree is low. In Indonesia, yields are in the range of 0.10–0.18 kg per tree for high-grade agarwood and 0.19–2.13 kg per tree for low-quality product (Soehartono and Newton 2001). Even though market prices for agarwood are higher than for other NTFPs, collectors need to harvest more trees because of low yields; harvesting is labour-intensive, given the low natural abundance of agarwood-producing trees.

In recent years, agarwood plantations have been established in several countries, including Bangladesh, India, Indonesia and Malaysia, as an alternative means for producing agarwood (Liu et al. 2013; Akter et al. 2013). Such plantations, if successful, would enable global demand to be satisfied without the destruction of naturally occurring specimens (Akter et al. 2013). In plantations, agarwood production needs to be artificially stimulated (Liu et al. 2013), for which various techniques exist. For example, trees are mechanically wounded with blades, or holes are drilled into the trunk and roots in which tubes are inserted so the wounds cannot heal (Akter et al. 2013). Adding syrup or chemicals can also trigger infection and stimulate agarwood production. Sometimes the holes are directly inoculated with a fungus, *Fusarium* species (Akter et al. 2013). Agarwood trees treated in this way can develop agarwood as young as three years old; in natural settings, trees can only be harvested after 20–30 years (Faizal et al. 2016). Nevertheless, the agarwood produced in plantations is considered to be of relatively low quality (Kanazawa 2016; Akter et al. 2013), and much of the agarwood traded today is still from wild trees (Kanazawa 2016).

Management possibilities and potential

In a study in Malaysia, indigenous Penan people reported that they harvest agarwood by cutting a small hole in the bark to check if the tree has produced agarwood. If they find resin, they cut out the agarwood with an axe without felling the tree (Kanazawa 2016). The population of agarwood-producing trees managed in this way is stable, with no harvesting by outsiders, indicating that the harvesting method could be sustainable (Kanazawa 2016). In another study of Penan communities in Borneo, all encountered agarwood-producing trees showed signs of previous incisions but were still producing agarwood and seemed in good condition (Donovan and Puri 2004). In northern Viet Nam, communities cut holes in the trunk that are kept open by regular chipping (similar to the methods applied in plantations). This method stimulates the production of agarwood, which can be extracted regularly if the tree remains alive (Akter et al. 2013). Three harvesters in the Penan community in Malaysia stated that they received USD 366 for 4.35 kg of agarwood, which is a remarkable price and indicates a high quality of agarwood. The Penan harvesters confirmed that the returns from agarwood exceed returns from other income sources, such as rattan handicrafts (Kanazawa 2016).

In 2011, the Malaysian government created a programme called *Tana' Pengida Pengurip Penan* (the "Penan Peace Park") with the objective of ensuring indigenous rights, promoting ecosystem protection and enabling the local economic development of indigenous communities (Kanazawa 2016). The focus of the programme is to foster the commercialization of NTFPs as a source of income (Kanazawa 2016).

An analysis of the impacts of harvesting on the population of *Aquilaria malaccensis* conducted in Indonesia found that, even though agarwood harvesting was destructive, the population continued to increase if only trees with a dbh greater than 10 cm were harvested (Soehartono and Newton 2001). In the case of *A. macrocarpa*, the model indicated that only trees with a dbh greater than 30 cm should be harvested to avoid population declines (Soehartono and Newton 2001). According to the analysis, *A. malaccensis* was relatively insensitive to a short logging rotation (the minimum rotation interval tested was five years), but *A. microcarpa* populations declined in the simulation when the logging rotation was less than 15 years (Kanazawa 2016).

Scientists at the University of Minnesota have developed a new technique for inducing high-quality agarwood production (Blanchette et al. 2015). The technique involves drilling holes into the trunk and keeping these open with small plastic pipes, and various chemical compounds and fungi are added (Blanchette et al. 2015). Nevertheless, no published assessment of agarwood quality using this technique has been found in the literature. An agarwood inducement kit has been created to enable growers to apply the technique (Blanchette et al. 2015).

Liu et al. (2013) presented an innovative method to induce agarwood production in *Aquilaria* called the "whole-tree agarwood-inducing technique" (Agar-wit). It involves the injection of a transfusion of agarwood inducers directly into the xylem of trees, from where they are transported through the whole tree. This technique enables the harvesting of 2.4–5.8 kg of agarwood per tree after six months (Liu et al. 2013), with agarwood formed throughout the whole tree; higher-quality resin is produced when agarwood formation spans 12–20 months. Even though Agar-wit agarwood has similar resin content and high alcohol-soluble extractive to wild agarwood, there are differences in colour and aroma (Liu et al. 2013).

Aquilaria species can be intercropped with other species, and it has been grown successfully with banana, rubber, teak and oil palm in Southeast Asian agroforestry systems. This is a promising approach because it enables the earning of other income while the agarwood is forming and provides needed shade for *Aquilaria* seedlings (Blanchette et al. 2015).

Market evaluation of the commercialization of agarwood

The history of agarwood trading dates to the first century of the common era in China (Kanazawa 2016). India was one of the earliest sources of agarwood in the international market in the thirteenth century (Oud Selection 2017). The global trade accelerated in the mid-1970s with rapid economic growth in Asia and the Middle East (Lim and Awang Anak 2010; Sampson and Page 2018). Demand continues to rise today, with only 40% of worldwide demand met (Plantations International undated). Thus, prices are high for agarwood, and a lucrative market exists for agarwood harvested in the wild, even though this is now illegal in most countries in East Asia (Soehartono and Newton 2001).

The main markets for agarwood are the Middle East and East Asia (Plantations International undated). In 1995, it was estimated that 30% of the agarwood exported from Borneo was traded to the East Asian market and 70% went to markets in the Middle East (Jensen 2009). Seven hundred tonnes of agarwood were traded internationally in 1997, with Indonesia and Malaysia the leading exporters worldwide (Oud Selection 2017). Even though volumes are relatively small in comparison to those associated with the timber trade, the financial returns are remarkable (Oud Selection 2017). Agarwood is known as the world's most valuable NTFP per unit volume (Soehartono and Newton 2001; Jensen 2009). Lower-quality agarwood chips might sell for about USD 20, but high-quality agarwood chips can cost tens of thousands of United States dollars per kg (Akter et al. 2013). It has been reported that shops in Kyoto, Japan, have sold high-quality pieces of agarwood for up to USD 250 per g (Kanazawa 2016).

The oil distilled from agarwood sells in the range of USD 10 000–14 000 per litre, with prices reaching as high as USD 20 000 per litre (Akter et al. 2013). The total global trade is estimated at USD 6–8 billion per year (Akter et al. 2013).

In the Lao People's Democratic Republic, a local harvester will collect 128–169 kg of agarwood from *A. crassna* in a working year of 21–71 days, earning

USD 88–435 (Jensen 2009). Most of the collected agarwood is of lower quality. More than 94 000 kg of low-quality agarwood is harvested per year in the Lao People's Democratic Republic, for an average return to harvesters of USD 0.3 per kg (and a price of USD 1.2 per kg in the retail market); in contrast, only 2.45 kg of the highest-quality agarwood is harvested per year, at a value of USD 5914 per kg in local markets (and USD 39 454 per kg in retail stores) (Jensen 2009).

According to the study in the Lao People's Democratic Republic, harvesters earn, on average, 13% of the product value at the retail stage, which seems quite high (Jensen 2009). The costs incurred by harvesters during collection are mainly associated with transportation. A qualitative analysis concluded that agarwood collection is profitable for harvesters in the Lao People's Democratic Republic (Jensen 2009).

Box 9: Supporting producer countries in the legal trade of agarwood

ITTO has conducted extensive work on agarwood, including by assisting producer countries to identify strategies that balance the conservation and use of wild agarwood populations and the increased use of planted material. Under the ITTO–CITES Programme, ITTO and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) co-organized the Asian Regional Workshop on the Management of Wild and Planted Agarwood Taxa in 2015, which addressed topics such as the formulation of non-detriment findings for agarwood; the role of plantations in balancing harvests from natural forests; the management and silviculture of natural agarwood; plantation-grown agarwood: potential resources and management; managing agarwood-producing species in natural forests and plantations; agarwood trade trends; and country reports from Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Nepal, Thailand and Viet Nam. ITTO and CITES continue to cooperate on the sustainable trade of various tropical tree species, including agarwood, through the CITES Tree Species Programme.

For more details see www.itto.int/news_releases/id=4279 and www.itto.int/cites_programme

Conclusions

- Agarwood-producing tree species, mainly *Aquilaria* and *Gyrinops* species, are now rare in the wild. Several *Aquilaria* species are on the IUCN Red List of Threatened Species, some categorized as critically endangered.
- Agarwood accumulates in the wood of the trunk, roots and branches, and its harvesting often involves felling and cutting open the whole tree. It is difficult to recognize agarwood-producing trees before harvesting, which leads to indiscriminate harvesting. With demand and the prices paid for agarwood growing continuously, an illegal trade is flourishing.
- The quantity of resin obtained from a single agarwood-producing tree in the wild is low, at 0.10– 2.13 kg. Therefore, harvesters often need to fell numerous trees.
- In Sarawak, Malaysia, Penan people harvest agarwood without felling trees, cutting out those parts of the trees that contain resin. This seems to be a sustainable method in the wild, given that the population of agarwood-producing trees in areas harvested by the Penan is stable, with numerous trees with indications they had previously been harvested judged to be in good condition.
- In Indonesia, thresholds have been developed for minimum dbh for agarwood harvesting and minimum logging rotations; if adhered to, these thresholds should make it feasible to harvest *Aquilaria* species in the wild sustainably.
- Plantations could satisfy worldwide demand for agarwood without contributing to the destruction of tropical forests. Various methods of agarwood inducement exist, including the mechanical wounding of trees, chemical irritation and fungal inoculation. Recent approaches usually combine various methods.
- Innovative approaches to agarwood inducement have yielded remarkable quantities of agarwood within a few months or years, but the quality of plantation-grown agarwood is lower than the highest-quality agarwood obtained in the wild.
- Agarwood is the world's most valuable NTFP. The highest-quality agarwood chips have been known to sell for USD 250 per gram, and the oil distilled from agarwood can command a price of USD 20 000 per litre. In the Lao People's Democratic Republic, local agarwood harvesters earn up to USD 435 per year. Thirteen percent of the product's retail value is retained by local harvesters; given their low costs, it seems to be a profitable activity for them.

Damar resin (dipterocarps)

Common name: gum damar, resin damar, harsa, damar mata kucing, damar gelap

Present in: India and Southeast Asia

Harvesting season: entire year

Harvesting yields: 5–48 kg resin per tree per year

Main uses: caulking boats; incense; paints and varnishes

Substitutes: synthetic resins

Tree density in the forest: 0.07–0.3 trees per ha

Harvesting practices: tapping the tree by cutting holes about 10 cm wide and 15 cm deep into the trunk to stimulate resin flow; collection of crystallized resin from the forest floor

Managed dipterocarp forests, Malinau, Kalimantan, Indonesia. Photo: © J. Blaser

Dipterocarpaceae is a dominant tree family in the tropical forests of Southeast Asia, occurring in Borneo, Sumatra, Java, the Malay Peninsula, the Philippines, Sri Lanka and elsewhere (Corlett and Primack 2005). Dipterocarps are among the tallest of the rainforest trees, with heights up to 50 m, and they occupy various habitats, from coastal to inland, in well-drained to poorly drained soils and in primary and secondary forests (Corlett and Primack 2005). More than 500 species of dipterocarp are known (Corlett and Primack 2005). Damar resin is harvested mainly from species in the *Balanocarpus*, *Hopea* and *Shorea* genera (Anonymous undated).

The main economic product of dipterocarps has long been timber. *Shorea robusta* (sal), for example, has been used for timber in India for more than 2000 years (Appanah and Turnbull 1998). Dipterocarp NTFPs include damar, nuts and camphor (Appanah and Turnbull 1998); *Dryobalanops aromatica* was once a primary source of camphor, the trading of which between China and India dates to the first century of the present era (Appanah and Turnbull 1998).

All dipterocarp species produce damar resin when the bark of the tree is wounded (Corlett and Primack 2005; Appanah and Turnbull 1998). As a trading term, damar refers to all kinds of resins from dipterocarps, including oleoresins. Strictly, damar refers only to solid resin formed once essential oils evaporate from the exudates (Appanah and Turnbull 1998).

Damar gum is used traditionally by local people for caulking boats and the manufacture of torches and handicrafts (Appanah and Turnbull 1998; Torquebiau 1984). It is also used in cremations, as incense (mainly sal damar) and in the production of paints, varnishes and linoleum (Torquebiau 1984; Appanah and Turnbull 1998).

Only a few species are commercially important for damar. These include the following:

- damar mata K caulking kuching (*Hopea micrantha*), damar penak (*Neobalanocarpus heimii*) and damar temak (*Shorea crassifolia*) in Malaysia;
- sal damar (*Shorea robusta*) and white damar (*Vateria indica*) in India;
- rock damar (*Hopea odorata*) in Bangladesh, India and Myanmar; and
- Batavian damar (*Shorea wiesneri*) and damar mata Kuching (*Shorea javanica*) in Indonesia (Java and Sumatra) (Appanah and Turnbull 1998; Kusters et al. 2008).

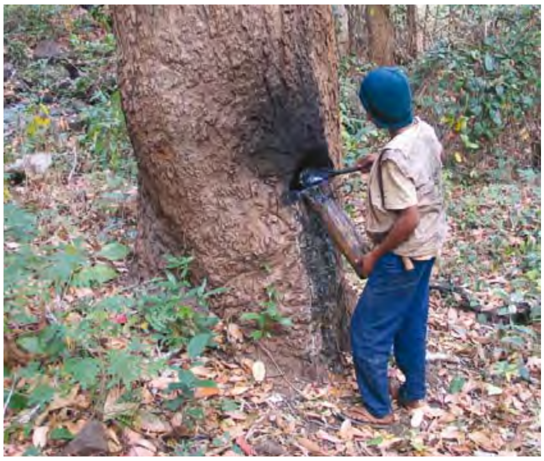
Conflict of use

Dipterocarp species comprise 80% of timber exports from Southeast Asia (Kettle 2009), and the timber is renowned for its long-term resilience and resistance (Kettle 2009). There is a conflict of use between timber and damar resin. For example, *Shorea robusta* produces high-quality hardwood and is also the source of sal resin. In Indonesia, the price of dipterocarp species reached IDR 1.5 million (USD 108) per cubic metre in 1998 compared with IDR 3800–4100 per kg (USD 0.42–0.45 per kg) for damar resin (Kusters et al. 2008; Soetarto et al. 2001).

Damar resin tapping does not damage trees (Foppes et al. 1997), but logging reduces tree availability in the wild (Kusters et al. 2008; Foppes et al. 1997). Even dipterocarps with lower-quality timber, such as *Shorea javanica*, are logged and used to produce plywood (Kusters et al. 2008; ShoreaOrg 2005; De Foresta et al. 2017).

Approaches for dealing with this conflict include regulation: the *Shorea* genus comprises some of the world's most valuable hardwoods, but only trees with

Damar resin extraction in the Philippines. Photo: © NTFP-EP



Damar resin extraction in the Philippines. © Eang Hourt/WWF

dbh > 50 cm can be harvested (ShoreaOrg 2005). Strict adherence to this regulation has helped ensure the continued abundance of *Shorea* species in several Asian countries (ShoreaOrg 2005).

Factors for negative outcomes in the harvesting of damar

The natural abundance of damar trees varies between 0.07 and 0.3 trees per ha, depending on the species (Appanah and Turnbull 1998); in cultivated damar agroforest systems, the density ranges from 100 to 190 trees per ha (Titiresmi 2006; Torquebiau 1984).

The abundance of damar trees in Indonesian forests has decreased since the 1880s. Demand for resin for industrial purposes, however, encouraged Indonesian farmers to develop damar agroforest systems (Kusters et al. 2008). Even though damar resin is still partly harvested in wild forests, the large part is now collected from such systems (Torquebiau 1984).

Damar agroforest systems are often developed in a transformation process. Wild damar trees are preserved during shifting cultivation and seedlings from the forest added (Torquebiau 1984; Appanah and Turnbull 1998). The production of dipterocarp seedlings is challenging, however, because of the short life span of the seeds, difficulties in transplanting them, and irregular flowering and fruiting (Torquebiau 1984).

Damar agroforests are under threat from conversion to more profitable land uses. For example, many farmers converted their damar forests into clove plantations between 1969 and 1980 during a boom in the price of cloves (Wollenberg and Nawir 2005).

In Krui, Sumatra, the productivity of damar agroforests decreased between 1995 and 2004 due to an increase in disease and tree death when farmers shortened the interval between harvests (Kusters et al. 2008). This was mainly in villages in the south, where the tradition of conserving damar gardens for future generations was weakest (Kusters et al. 2008). Traditionally, household heads are socially obliged to bequeath their damar agroforests to their eldest sons because the gardens are considered heritage rather than property (Casson 2005).

Management possibilities and potential

Damar agroforests in Sumatra date to the nineteenth century and have tree densities of up to 190 productive damar trees per ha, comprising 65% of all trees (Torquebiau 1984). These agroforests cover about 50 000 ha in Krui and 100 000 ha in Lampung (Torquebiau 1984; De Foresta et al. 2017; Titiresmi 2006).

Complex damar agroforests have conservation and biodiversity value because they provide habitat for many species of flora and fauna, show structural similarities to natural forests and provide local farmers with several sources of income (Kusters et al. 2008; De Foresta et al. 2017; Budidarsono et al. 2000). The understorey is usually scarce but the upper canopy is dense with durian, damar and other timber trees (Torquebiau 1984). Close to villages, fruit trees are common, and many birds and monkeys are present, as well as wild pigs (Torquebiau 1984).

Damar trees require little investment and provide a regular monthly return (Torquebiau 1984). Initially, damar seeds are planted under the shade of coffee or pepper plants. The trees become dominant in 5–15 years (Torquebiau 1984) and reach maturity at 20 years; they can form the main income source for farmers for up to 30 years (Budidarsono et al. 2000).

Damar collection provides approximately 50% of the income of farmers in rural Sumatra (Wollenberg and Nawir 2005; Torquebiau 1984). For the production of damar, holes approximately 10 cm in diameter and 15 cm depth are cut into the trunk. The holes are deepened at following collections, until new holes further up the tree are drilled (Appanah and Turnbull 1998; Torquebiau 1984). The resin is dried as drops or strings when harvested (Torquebiau 1984). Usually, trees located close to villages are tapped weekly and trees further away are tapped monthly (Torquebiau 1984).

Damar resin is also traditionally collected in other parts of Southeast Asia. Foppes et al. (1997) reported that, in Khammouan Province in the Lao People's Democratic Republic, locals collected the resin from the forest floor after it fell from trees, and more than 50% of household income was derived from "kisi" resin from *Shorea* species.

Market evaluation of the commercialization of damar

A damar tree can produce 4–5 kg of resin per month, with some trees capable of producing 8 kg per month (Torquebiau 1984). Assuming an annual resin production of 48 kg per tree and a tree density of 100 trees per ha, each hectare will produce 4.8 tonnes per year (Appanah and Turnbull 1998; Torquebiau 1984). Damar resin can be collected throughout the year, and one collector will tap an average of 20 kg of resin per day (De Foresta et al. 2004). A family usually needs to work for about five days per month in a damar garden to obtain one month's subsistence (De Foresta et al. 2004). Most of the income from damar agroforests is derived from the sale of damar resin and only about 10% comes from the collection of fruit (Kusters et al. 2008). Even though some farmers diversify their agroforests by adding pepper, coffee or oranges, the net return is similar (Kusters et al. 2008). Moreover, labour demands are higher for these other crops and the income earned is more seasonal (Kusters et al. 2008). Damar growers receive approximately 70% of the sale price, with the remaining share divided among village traders and wholesalers (De Foresta et al. 2004).

The price of damar resin has declined as it has been substituted increasingly by synthetic materials (Appanah and Turnbull 1998). In Indonesia in 1995, a price of IDR 4100 (USD 0.45) per kg could be obtained; this had dropped to IDR 3800 (USD 0.42) by 2004, a decrease of 7% (Kusters et al. 2008). The sale price was considerably lower in the Lao People's Democratic Republic, at LAK 150 (USD 0.14) per kg (Foppes et al. 1997).

Nevertheless, the market for damar resin can be considered stable (De Foresta et al. 2017; De Foresta et al. 2004). Damar gardens have existed in Indonesia for over a century; the resin has various traditional uses; and the market is still growing in some subsectors—such as use as an additive to soft drinks (De Foresta et al. 2017). The main export countries are Germany, Japan, Malaysia, Singapore and Taiwan Province of China (Appanah and Turnbull 1998). Indonesia exported 10 000 tonnes of *S. javanica* damar resin in 1995 (De Foresta et al. 2017).

Conclusions

- Damar resin is harvested from dipterocarps. There is a conflict of use between timber and NTFP extraction because dipterocarp timber is often valuable and widely traded. The strict regulation of timber harvesting, as it exists for *Shorea* species, can contribute to the conservation of tree stocks and reduce conflicts over use.
- The abundance of damar trees in natural habitats is low, at 0.07–0.3 trees per ha. Damar agroforestry systems developed in the nineteenth century due to high demand for damar resin. Today, only a small share of the damar volume is harvested in natural forests.
- Agroforestry systems for damar production often develop in a transformational process, whereby natural damar trees are preserved in shifting-cultivation areas and seedlings added from the forest. Damar agroforests have structural similarities to natural forests and provide farmers with various sources of income.
- Threats include the conversion of damar agroforests into crop plantations, overharvesting, and a consequent reduction in productivity due to an increased incidence of disease and tree death.
- Damar harvesting has a long local tradition, and some damar agroforests are more than 100 years old. Trees can be harvested throughout the year for at least 30 years after they reach maturity at approximately 20 years of age.
- Local people harvest up to 4.8 tonnes of resin per tree per year and tap about 20 kg of resin per day. Net returns are comparable with other crops, such as pepper, coffee and oranges.
- Even though prices have declined in recent years, the market for damar resin is considered stable, with demand high and some subsectors still growing—for example in the food industry as an additive to soft drinks.

Açaí (*Euterpe oleracea*)

Common names: açaí, açaí solteiro, huasai, açaí do Pará, palmiche, manaca, Brazilian berry

Present in: Brazil, French Guiana, Guyana, Venezuela

Harvesting season: wetlands, July–December; permanent dry areas, July–October

Harvesting yields: each açaí stem produces 120 kg of fruit per year; 1160 kg/ha/year of fruits are harvested in unmanaged forest areas

Main use: açaí juice, palm heart

Substitute: bacaba juice

Tree density in the forest: widespread (128–208 palms per ha); large populations in flooded forests

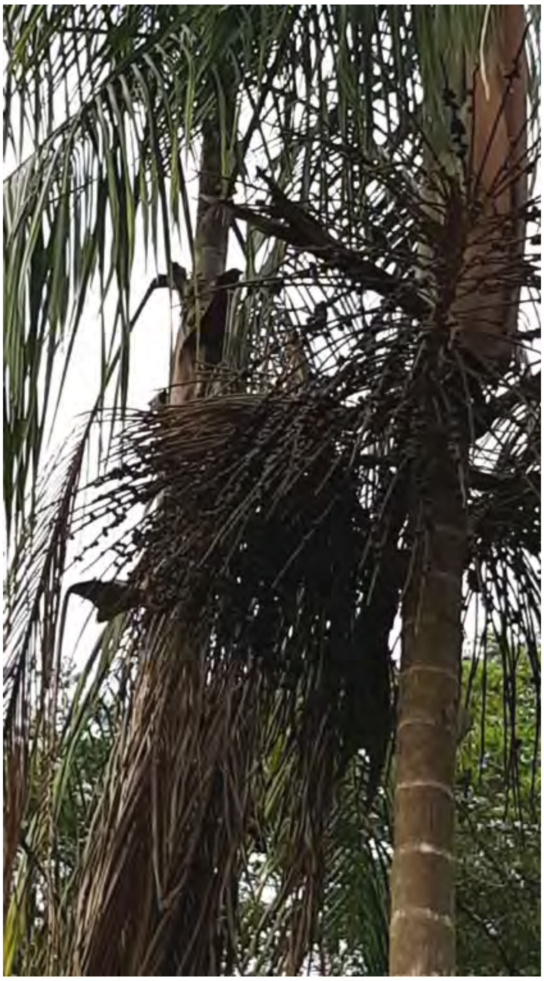
Harvesting practice: people with ankle straps climb the palm using footlings to collect fruit bunches; when on the ground, the fruits are stripped from each stalk manually

Handling: the fruits are macerated with the addition of warm water to extract the pulp

Euterpe oleracea is a palm species native to the Amazon Basin, with a broad distribution encompassing Brazil, Colombia, Ecuador, French Guiana, Guyana and Venezuela (Shanley et al. 2011; Vallejo et al. 2016). The palm grows best in floodplain forests but is also found in non-flooding areas (*terra firme*) in perhumid subclimates. It is generally multistemmed, with 4–9 stems per clump, each trunk reaching a height of more than 25 m and a diameter of 9–16 cm at breast height (Shanley et al. 2011).

Indigenous peoples originally cultivated and encouraged the spread of the palm in the Amazon. As a significant source of calories, açaí juice was consumed traditionally with manioc flour and fish. Today, the fruit is still valued by local people as an accompaniment to meals, and it is also used as a dessert combined with sugar and other fruits. The palm heart is edible and the seeds are used to make jewellery. *Euterpe oleracea* is the main source of açaí winefruit, but other species of *Euterpe*, such as *E. precatoria* and *E. catinga*, produce similar fruits (Smith 2015).

Açaí fruit is rich in antioxidants, and there is some evidence of anti-inflammatory, cardioprotective and neuroprotective properties (Smith 2015; Vasconcelos et al. 2019). There is a strong regional market for açaí in Brazil, where the frozen pulp is consumed as a trendy, healthy source of energy and calories. In the cosmetics industry, açaí oil extracted from the fruit is used in the production of body lotions and hair



The açai palm. Photo: © Jarmilly Gondim/PWA

products because of its richness in fatty acids and its moisturizing properties. The international market for açaí grew rapidly in the 2000s, mainly in the United States of America, where the juice became popular as a "superfood".

Conflict of use between açaí heart and fruit

The juice of açaí fruit has been consumed for thousands of years; the local custom is to plant açaí seedlings after the harvest of annual crops, integrating it with other fruit trees in homegardens (Smith 2015). Palm hearts produced from *Euterpe* palms became a marketable product in northern Brazil in about 1970. A conflict arose between the use of the fruit and palm hearts because palm hearts are produced by cutting the stems, thus reducing the yield of the fruit. This was of particular concern for some species: *Euterpe oleracea* is multistemmed and regenerates after palm harvesting, but *Euterpe precatoria*, which is single-stemmed, is killed by

An açaí stand in the PWA forest in the Brazilian Amazon. Photo: © J. Frizzo

palm-heart harvesting. Thus, the harvesting of palm heart from single-stemmed palms might lead to overexploitation. The single-stemmed palm *Euterpe edulis*, for example, which was harvested without management plans, is almost commercially extinct in southern Brazil (Smith 2015). The Brazilian Institute of Environment and Natural Resources forbade palm-heart harvesting without management plans in 1989 (Shanley et al. 2011).

Açaí fruit is still the main consumed NTFP of *Euterpe*, especially in local markets (Weinstein and Moegenburg 2004). The preference for the fruit in local markets was confirmed by a study in the Amazonian estuary, which showed that harvesters might collect the palm hearts in addition to the fruit but only to improve the yield of fruit on a plant's remaining stems (Weinstein and Moegenburg 2004). Harvested palm hearts are exported to southern Brazil, France and the United States of America (Shanley et al. 2011; Smith 2015).

Factors for negative outcomes in the harvesting of açaí

Observations and data on the harvesting of açaí fruit and palm hearts have been collected since 1980. In regions where açaí is cultivated, there is a tendency for forests to transition towards açaí plantations (Weinstein and Moegenburg 2004). The forest in the Amazon estuary in Pará, Brazil, which is mainly covered by *E. oleracea*, is not considered pristine because it has been influenced for centuries by logging, agriculture and the collection of NTFPs (Weinstein and Moegenburg 2004). Açaí harvesting in natural forests significantly alters vegetation structure, such as by increasing açaí clump density and reducing overall tree density and forest canopy cover, and there is also a near complete loss of vines, lianas and large woody trees. The development of açaí-dominated forests (Weinstein and Moegenburg 2004) is due to the clearance of understorey vegetation around the palms to encourage açaí growth and increase fruit production, as well as to make it easier to collect fruit (Weinstein and Moegenburg 2004). In their study in the Amazon estuary, Weinstein and Moegenburg (2004) reported that, in most survey transects, vegetation was cleared around açaí clumps to a radius of more than 3 m and, in some transects, 10 m was cleared around about 50% of the palms.

Converting forests into palm plantations can cause the loss of biodiversity. This was observed in a study by Freitas et al. (2015) in Amazonian floodplain forests, where areas with community management for açaí production contained an average of 200 palm stems per ha, as proposed by the Secretary of Environment for Pará State for best-practice management. The study surveyed biodiversity in 24 plots (0.1 ha in size) in managed açaí production forest and 12 plots in unmanaged forest. A negative linear relationship was found between açaí density and tree species richness, such that tree species diversity was 50% lower in forest where the density of açaí trees was 200 stems per ha compared with the unmanaged control (Freitas et al. 2015). In the former area, more than 60% of trees were *E. oleracea*, a density that was about seven times higher than in the control areas (Freitas et al. 2015). Even in "best-practice" management, therefore, biodiversity losses occur, proportional to açaí palm density (Freitas et al. 2015).

A further consequence of the transition of natural forests towards açaí plantation-like forest in the Amazon might be effects on rainfall patterns and soil hydrology. In one study in Amazonia, in a region where evapotranspiration is responsible for about 74% of the annual rainfall, converting natural forest to an açaí palm plantation reduced evapotranspiration by about 40% (Kunert et al. 2015). The açaí plantations had a much lower leaf area index (1.8) compared with natural forest (8.0); thus, intercepted rainwater and transpiration were lower in the plantations and soil evaporation and runoff were higher (Kunert et al. 2015).

Açaí fruits are perishable and must be processed within eight hours of harvesting (Sabbe et al. 2009; Weinstein and Moegenburg 2004), and their sale as fresh goods is limited to local and regional markets. The pulp can be traded internationally, however, when pasteurized, packaged and frozen. The quality of frozen açaí pulp is variable and depends on the processing method used, and contamination is possible (Sabbe et al. 2009). Palm hearts are less perishable, with processing required within five days of harvesting (Weinstein and Moegenburg 2004).

Management possibilities and potential

The management and commercialization of açaí has potential for the following reasons, among others:

- Considered a superfood due to its nutrient composition, açaí fruit is highly desired, and market growth can be expected (Sabbe et al. 2009).
- *E. oleracea* is a dominant, productive palm, occurring at high densities (Raupp 2010), such as up to 280 stems per ha in Acre, Brazil (Lopes et al. 2019). Palms grow alongside rivers and in wet zones, so locals can reach them easily by boat (Weinstein and Moegenburg 2004).
- Fruit harvesting is from February to August in Pará, Brazil (Muñiz-Miret et al. 1996). Off-season production can also be stimulated by removing newly formed racemes, with such fruit fetching higher prices in regional markets (Muñiz-Miret et al. 1996).
- Two economically important NTFPs can be harvested—the fruit and the palm heart. This provides flexibility and income security for local people as prices and consumption patterns change (Weinstein and Moegenburg 2004).
- There is a long history of açaí fruit-picking and therefore local markets—and pulp-processing industries—already exist. NTFP extraction can be more profitable than other land uses such as timber extraction and agricultural production on flood-prone land (Weinstein and Moegenburg 2004).
- Markets are growing. The market in Brazil developed quickly in the 1980s as migrants from rural areas—with their liking for açaí—contributed to rapid urban growth. By 2002, açaí consumption in Belém was twice that of milk, with an average annual consumption of 60 litres per capita (Brondízio et al. 2002). More recently, international markets have emerged, with the United States of America the largest export market for Brazilian açaí pulp (Menezes et al. 2011).

The harvesting of açaí can change vegetation structure, and approaches are therefore needed to minimize its ecological impact. The growth rate and fruit output of açaí palms increase after "cleaning" (i.e. practices to remove understorey vegetation, canopy trees and lianas); on the other hand, some local people minimize cleaning to conserve forest diversity, thus maintaining other NTFPs that could act as insurance as markets change (Weinstein and Moegenburg 2004).

Another approach to minimizing ecological impact would be to increase the economic return obtained from açaí harvesting and processing, thereby reducing pressure on local people to increase production through cleaning or by harvesting larger areas. This could be achieved by increasing production in the Northern Hemisphere winter, when demand (and therefore price) for açaí is highest (Weinstein and Moegenburg 2004).

Another way to increase the economic return while promoting sustainable harvesting practices is certification. Several studies have shown that the ecological impacts of açaí harvesting on forest composition and structure must be taken into consideration in the certification process (Weinstein and Moegenburg 2004). An example of a cooperative that has been able to increase its income through certification is the Cooperative of Bailique Extractive Producers (AmazonBai) at the mouth of the Amazon River in the Brazilian state of Amapá. AmazonBai successfully organized its 120 collectors in 30 communities to create a company to sell açaí winefruit and certify its production, including from the FSC. After the formation of the cooperative and the certification of its product, the price of an açaí basket (14 kg) doubled from USD 8 in 2012 to USD 16 in 2017 (Alves and Ramos 2019). The cooperative undertakes the marketing of its products without intermediaries, and 5% of the sale of every basket is invested in the community school (Alves and Ramos 2019). The cooperative plans to process the fruit in its own communities and to find niche markets for various açaí products. Additionally, it plans to use açaí powder to enrich the school meals of local children (Alves and Ramos 2019).

Another approach to açaí production is co-management with timber production. In a study on managing smallholder timber production and açaí in the Amazon estuary, Fortini and Carter (2014) found that the sale of açaí fruits in a cultivated area of 12.5 ha provided the same income as legal timber extraction on 532 ha. The study did not describe the combined management approach nor estimate the revenue generated by co-management, although it noted that loggers often directed the felled trees away from açaí clumps and cut old stems (Fortini and Carter 2014). The co-management of açaí and timber, which could include the integration of inventories and logistics, has potential because the palm is often abundant in timber production areas.

Market evaluation of the non-timber forest product

Demand for açaí has been rising, with an estimated 300 000 tonnes of açaí products sold globally in 2016 (Future Market Insights 2017). The market value of açaí is expected to rise from about USD 0.5 billion in 2016 to nearly USD 2 billion in 2026 (Future Market Insights 2017).

Brazil is the main producer of açaí, at 200 000 tonnes in 2017; 4000 tonnes of palm heart were also extracted (IBGE 2017). Most açaí berries sold are from cultivated areas (Calderon 2013). In Brazil, 98.3% of the national output is in Pará (Vallejo et al. 2016).

Palm heart is produced from *Euterpe oleracea* in Colombia; from *E. precatoria* in Bolivia and Peru; and from *Bactris gasipaes* in Costa Rica and Ecuador (Brokamp 2015). In a managed area, about 190 kg per ha of palm hearts can be extracted annually, assuming a density of 700 trees per ha (Shanley et al. 2011). The market share of plantation-grown palm-heart products, especially of *B. gasipaes*, is growing, replacing the wild harvesting of *Euterpe* species (Brokamp 2015). Ecuador is now the leading exporter of palm hearts, accounting for 55% of the international palm-heart trade, followed by Costa Rica, at 20% (Brokamp 2015).

The main importing countries of palm hearts are France and the United States of America (Smith 2015). France (13 000 tonnes in 2015) accounts for 76% of palm-heart imports into the European Union and for 27% of imports worldwide. Palm heart is considered a delicacy in the country and is prepared in a similar way to asparagus and artichokes (Vallejo et al. 2016). A 400 g can of palm hearts sells for about USD 5 in French supermarkets (Vallejo et al. 2016).

A single *E. oleracea* palm will produce about 20 kg of açaí fruit per year (Lopes et al. 2019). In Acre, Brazil, men and children collect the fruits and women process them. Harvesters can climb 10–20 palm stems per day, and a family might collect 0.9 tonnes of fruit per year. The price paid varies by season and over time. On average, açaí fruit sells in local markets for USD 0.5–0.7 per kg and the winefruit for USD 2 per litre (Lopes et al. 2019; Shanley et al. 2011). The average annual household revenue is USD 57 per ha per year, of which açaí collection contributes 17%, substantially higher than the estimates for other NTFPs such as Brazil nut and rubber (Lopes et al. 2019).

Prices paid in the market in Belém are twice as high at the end of the season in January than at the beginning of the season in August and even higher during the off-season. Moreover, prices have increased drastically recently with growing national and international demand. A14 kg basket in Belém sold for USD 1–5 in 1995 and for more than USD 30 in 2008 (Shanley et al. 2011). Compared with palm hearts, açaí fruit production is more lucrative. The market value of fruit production corresponds to USD 9.8 per palm stem per year; the income obtained for palm heart is USD 0.1 per stem, with the additional damage to the tree (Brokamp 2015).

Nevertheless, processors and exporters gain the largest share of the profit (Zerrer 2009). In 2009, açaí juice fetched USD 2 per litre in local markets, USD 4–6 in the regional market in Pará, and USD 16–40 in the United States of America (Zerrer 2009). The international market for açaí pulp was estimated to be 30 000 tonnes in 2007 and rising (Brokamp 2015). Retail prices for açaí powder in Europe and the United States of America are in the range of USD 70–340 per kg, depending on the quantity purchased (Brokamp 2015).

Conclusions

- *Euterpe oleracea* is a native and widespread species in the Amazon Basin, where it is a popular food among local people. There are well-established local markets, and there has been rapid market growth recently in Brazil, Europe and the United States of America. Açaí is considered a superfood because of its high antioxidant and anti-inflammatory properties. It is traded in the form of frozen pulp.
- In contrast to açaí fruit, local people don't consume large quantities of palm hearts; instead, this product is exported to other markets, such as those in southern Brazil and in France and the United States of America. There is potential for conflict of use between açaí fruit and palm hearts because palm-heart harvesting causes the death of single-stemmed palm species (e.g. *E. edulis*).
- Açaí cultivation alters forest structure. One study found a negative linear relationship between the density of açaí palms and tree species richness, with forests in which açaí tree density is 200 stems per ha containing only half the tree species diversity of unmanaged forests. Evapotranspiration is estimated to be 40% lower in areas with açaí plantations than in nearby natural forests.
- To minimize negative ecological impacts, some land managers choose to avoid the removal of understorey vegetation to stimulate the growth of açaí palms, with the benefit of achieving a more diverse forest with a wide variety of NTFPs. Further research is needed on the ecological and economic impacts of such an approach.
- A grower cooperative, AmazonBai, has shown that achieving certification can help stimulate off-season harvesting and local processing while increasing economic returns and ecological sustainability. Since certification, AmazonBai has doubled the sales price of açaí and now plans to process fruit in the community.
- There is no experience in the co-management of timber and açaí fruit. The palm is abundant in low-lying areas where timber extraction is generally not allowed, and there is potential for such co-management in production forests.
- The market for açaí is expected to exceed 1 million tonnes per year by 2026. Plantation-grown palm hearts, especially of *B. gasipaes*, are replacing palm hearts obtained from wild *Euterpe* palms.
- The revenue earned by açaí harvesters is substantially higher than for many other NTFPs and more than for palm-heart harvesting. Even though the prices for açaí have increased, however, processors and exporters obtain the largest share of the profit. A challenge is to increase the share of profit for local harvesters, for example through cooperatives that process the fruit locally.

Wild cocoa (*Theobroma cacao*)

Common names: cocoa, cacao, food of the gods

Present in: South America, Central America, Mexico, West Africa, Southeast Asia

Harvesting season: year-round, but the main seasons are November–January and May–July

Harvesting yields: 50–60 fruits per tree per year and 7–9 kg of dried beans per tree per year

Main use: cocoa solids and butter are used for chocolate production and in the cosmetics industry

Substitute: no substitutability

Tree density in the forest: high (forming part of the lower forest stratum)

Harvesting practices: involves knocking the fruit to the ground by climbing or by using long poles

Handling: the beans are removed from the cocoa fruit, fermented in wooden boxes and dried in the sun

Wild cocoa. Photo: © S. Obladen/Helvetas

Theobroma cacao, a tree species in the Malvaceae family, is native to the Amazon Basin, with the centre of origin in the upper Amazon (Loor et al. 2009). It is a small, shade-grown tree that grows in humid, high-rainfall climates and can attain a height of 25 m in the wild (Pence 1989; Lachenaud et al. 2007). Cocoa beans develop in ovoid pods, with each pod containing 25–75 beans; they are white in colour, turning violet-brown when fermented and dried (Kim et al. 2011). Cocoa beans are the source of cocoa solids and butter (the main ingredients for chocolate) and are also used in the cosmetics industry (Kim et al. 2011; Sereno et al. 2006).

The fruits take 4–8 months to mature. After harvesting, the beans are fermented for 5–6 days,[15] either in heaps on banana leaves or in wooden boxes on layers of banana leaves, and then dried for about 14 days. The beans are roasted and ground to form chocolate liquor; edible chocolate is produced by mixing the liquor with cocoa butter and sugar (Perera and Smith 2013).

There are three major morphogenetic groups of domesticated cocoa: criollo, forestero and trinitario. Criollo varieties produce red or purple pods with an uneven surface; they were first cultivated by the Mayans in Central America, and Christopher Columbus collected samples in 1502 (Loor et al. 2009; Lachenaud et al. 2007; Perera and Smith 2013). Today, criollo occurs throughout South America, Central America and southern Mexico, although it is rare because of its susceptibility to disease (CEPLAC undated; Badrie et al. 2015). Forastero trees, which produce relatively smooth, hard pods, occur mainly in the Amazon, French Guiana, Guyana and Suriname (Loor et al. 2009; Lachenaud et al. 2007). Cocoa—from the forestero subtype amelonado—was introduced to Africa by the Portuguese in 1879 (Pence 1989). Trinitario is a hybrid of criollo × forastero trees that was imported into Trinidad in the eighteenth century and has variably shaped and coloured pods (Lachenaud et al. 2007; Loor et al. 2009). Ninety-five percent of the cocoa in world markets is from forastero trees, which grow vigorously and produce beans with a high fat content (Pence 1989; Badrie et al. 2015). Cocoa from criollo and trinitario trees produces chocolate of superior quality, but the combined market share of these two varieties is only about 5% (Badrie et al. 2015).

The Aztecs used cocoa beans as a currency and for a drink called *chocolatl*, which literally means "hot water" (Pence 1989; World Cocoa Foundation 2018). Spanish colonizers later added sugar to the bitter cocoa and brought it to Europe, where it became increasingly popular in high society as a hot drink (World Cocoa Foundation 2018). Solid chocolate was first produced in 1850 by adding cocoa butter to chocolate powder. Chocolate became highly popular around the world during the industrial revolution; today, more than 4.5 million tonnes of cocoa beans is traded annually (World Cocoa Foundation 2018).

Conflict of use

The timber quality of *Theobroma cacao* is low due to its low durability and the small dbh of cocoa tree stems and their frequent branching; thus, cocoa

15 Fermentation is important for the development of the aroma (Perera and Smith 2013).

wood is used only locally as woodfuel. Therefore, there is no conflict in the use of cocoa beans and cocoa timber (Fern 2019).

Factors for negative outcomes in the harvesting of wild cocoa

Numerous pests and diseases affect cocoa. Three important fungal diseases are *Moniliophthora roreri*, which causes frosty pod disease; *Phytophthora* species, which cause blackpod; and *Moniliophthora perniciosa*, or witch's broom disease.

Witch's broom disease infects all parts of the tree (shoots, flowers and fruits) and leads to hypertrophic, deformed growth with terminal broom-like appearances. During the rainy season, the pathogen appears as a pink mushroom (Meinhardt et al. 2008). The disease was first described in the eighteenth century in the Amazon, and it can cause crop losses of up to 90% (Meinhardt et al. 2008). In Ecuador, which was the largest producer worldwide in the 1920s, the disease reduced total production by half. In Bahia, Brazil, witch's broom disease had catastrophic effects on local cocoa production in the 1980s and 1990s, cutting it from 347 000 tonnes to 141 000 tonnes over a ten-year period (Meinhardt et al. 2008; Griffith et al. 2003). *Moniliophthora perniciosa* has not spread to West Africa or Southeast Asia (Meinhardt et al. 2008). Some clones of *Theobroma cacao*, mainly of the forestero type, show natural resistance to *M. perniciosa* (Meinhardt et al. 2008). Witch's broom disease is rare in the wild, probably due to the lower density of cocoa trees (Griffith et al. 2003).

Globally, seven *Phytophthora* species are known to affect cocoa; it is currently the disease causing the highest losses of yield, estimated at 700 000 tonnes per year (Ploetz 2016). Blackpod disease occurs in humid conditions with high rainfall and often in shaded plantations. *Phytophthora palmivora*, which is present worldwide, causes crop losses of up to 20%; *P. megakarya* is endemic in West and Central Africa, where it often leads to the total loss of harvest (Guest 2007). The first symptoms are small black spots, which eventually lead to black, mummified pods. The fungus also infects the bark, leading to cankers, which cause the death of 10% of infected trees per year (Guest 2007). Amelonado-type forestero trees seem to be less prone to blackpod disease than trees of the criollo and trinitario types (Guest 2007).

Frosty pod disease is endemic in wild cocoa trees in parts of South and Central America (Bolivia, Colombia, Ecuador, Peru and Venezuela), where it can cause harvest losses of up to 90 percent (Lachenaud et al. 2007; CABI 2019). The disease is not yet present in Brazil, the Caribbean, Africa or Southeast Asia (CABI 2019). Symptoms only manifest in the pods. Initially, infected pods seem swollen and heavier than healthy pods and, inside, the beans appear necrotic and watery (Roehl 2018). Black spots appear and, eventually, the pods are covered by felty white fungal growth—which gives the disease its name (CABI 2019; Roehl 2018). The tree itself is not killed (CABI 2019).

Management possibilities and potential

Various approaches to disease control are described below.

- *Chemical control*: potassium phosphonate, a salt, has been shown to be effective against *P. palmivora*, and copper hydroxide was found to have good efficacy and low toxicity against frosty pod rot (CABI 2019).
- *Biological control*: various endophytic fungi have been shown to have a protective effect against diseases in tropical trees. In cocoa-producing trees, *Trichoderma stromaticum* parasitizes basidiocarps of *Moniliophthora perniciosa*, which causes witch's broom (Meinhardt et al. 2008); however, certain climatic conditions (high humidity and temperatures below 30 °C) are necessary for optimal results (Meinhardt et al. 2008). *Trichoderma ovalisporum* showed good results in the control of *M. roreri* in studies in Costa Rica and Ecuador (CABI 2019). Various endophytic agents, such as *Chaetomonium* species, are active against blackpod disease, but no commercial product is available yet (Guest 2007; Hung et al. 2015).
- *Genetic resistance*: various genetic trait loci for resistance in cocoa have been detected, which will be helpful for the development of pathogen-resistant cocoa clones through genetic marker-assisted selection (Guest 2007; Meinhardt et al. 2008). Alternatively, healthy plants from areas with high pathogen loads can be selected for breeding programmes because of their reduced susceptibility (Guest 2007; Meinhardt et al. 2008).
- *Integrated management*: the incidence of blackpod disease can be reduced by managing the canopy to increase the incidence of light in the cocoa canopy and by branch pruning and understorey weeding to increase airflow. Using mulches might reduce disease transmission by acting as a physical barrier to rain splash and by promoting the decomposition of *Phytophthora*-infected debris (Norgrove 2007; Neuenschwander et al. 2019).

Managed wild cocoa in the Bolivian Amazon. Photo: © Helvetas/Simon Opladen

A study in southern Pará, Brazil, has explored the possibility of "re-agroforestation" through the establishment of shade agroforests involving cocoa on lands where forests have been cleared (Schroth et al. 2016). Cocoa trees have the potential to grow as understorey under the canopies of forest trees. In the study area, 1.26 million ha of deforested land with high-quality soil was classified as potentially suitable for cocoa production (Schroth et al. 2016). In addition to potentially addressing the loss of native forest, such forest-like systems would have significant potential for mitigating climate change by increasing the carbon stock (Schroth et al. 2016; Norgrove and Hauser 2013). Cocoa agroforests can support diverse soil fauna assemblages and promote their activity, thus enhancing nutrient cycling (Norgrove et al. 2009). Cocoa is grown under the canopies of native trees in traditional *cabruca* systems in the Atlantic forest biome in southern Bahia, Brazil (Faria and Baumgarten 2007). Even though plant species diversity is much lower in this system than in natural forests, the species richness of bats can be retained if *cabrucas* are within 1 km of forest reserves (Faria and Baumgarten 2007). Bats are important actors in ecosystems and indicators of habitat integrity; it may be assumed that shade agroforest systems such as *cabrucas* close to natural forests serve as biological corridors connecting natural forest reserves (Faria and Baumgarten 2007). In a meta-analysis looking at the impact of shade in cocoa systems on biodiversity, Norgrove and Beck (2016) found that increasing amounts of shade had a positive impact on bird diversity, but effects on other taxa were mixed.

In La Paz, Bolivia, the Tacana indigenous people engage in the wild harvesting of cocoa as a traditional part of their culture (Anonymous 2018). The 45 families comprising these communities are all involved in this activity, harvesting various cocoa stands in an area of 3500 ha (Anonymous 2018). The harvesting of wild cocoa serves as an important additional income source, especially because cocoa production is one of the few activities that can be conducted in the rainy season. The quality of the chocolate produced has improved steadily in recent years through innovations in cocoa tree management and in harvesting and processing techniques (Anonymous 2018). This has led to an increase in the selling price of 83% since 2013; moreover, cocoa collected and processed by the Carmen del Emero Association of Wild Cacao Producers (APROCACE) won an international prize (Anonymous 2018). APROCACE now sells its cocoa to Chocolate Para Ti, one of Bolivia's leading chocolate producers (Anonymous 2018).

In Beni, Bolivia, the "beniano" cocoa tree is harvested in the wild by Original Beans, which produces fine chocolate in an organic and sustainable way (Original Beans undated). Beniano produces small beans, which cannot be processed by typical machines and have a strong flowery aroma. The chocolate produced from these beans is made in Switzerland by Felchlin. The chocolate can be purchased online and in many bricks-and-mortar stores, such as Marinello, a high-quality supermarket in Switzerland (Marinello undated), and in the United States of America.[16]

Another example of the successful commercialization of wild-harvested cocoa is in Purus, Brazil. A cooperative called Cooperativa Agroextrativista do Mapià e Médio Purus, which was founded in 2003 and now has more than 300 local harvesters as members (Cooperar undated), harvests wild cocoa that is then processed and sold by Hachez, a chocolate-maker in Bremen, Germany (Kassiopeia undated). In addition to wild cocoa, the cooperative sustainably produces vegetable oils; the objective it to provide local people with incomes and a better quality of life while protecting the forest (Cooperar undated).

Market evaluation of the commercialization of cocoa

Worldwide, cocoa production was estimated at 4 733 999 tonnes in 2017. About 73% of production is in Africa (especially Cameroon, Côte d'Ivoire, Ghana and Nigeria), 13% is produced in South America (Bolivia, Brazil and Ecuador) and 14% is in Southeast Asia (Indonesia, Malaysia and Papua New Guinea) (Sarbu and Csutak 2019). Almost 40% of the cocoa is processed in Europe—especially the Netherlands, which accounts for 31% of cocoa processing globally (Swiss Platform for Sustainable Cocoa undated). The largest importers are France, Germany and the United States of America (Badrie et al. 2015), and the highest per-capita consumption is in Belgium and Switzerland (Swiss Platform for Sustainable Cocoa undated).

In 2001, the global chocolate market was worth an estimated USD 40 billion, and the value of the total market—including other cocoa and cocoa-butter manufacturing industries, such as the cosmetics industry—was estimated at USD 70 billion (Badrie et al. 2015). Demand for cocoa is increasing by 3% annually (Wickramasuriya and Dunwell 2017).

Ninety percent of global cocoa production is by small-scale farmers. In most cases, such farmers cultivate 2–5 ha with low yields (e.g. an average of 0.42 tonnes per ha in Ghana) (International Cocoa Initiative 2017). Market prices for cocoa are volatile, fluctuating between USD 714 and USD 3775 since 2000 in response to the impacts of weather and pests (Swiss Platform for Sustainable Cocoa undated). In many countries, small-scale farmers earn considerably less than the global market price due to local trading structures, taxes and bean quality. In Côte d'Ivoire, for example, farmers received only 40–50% of the world market price in the last ten years, in many cases less than USD 1.25 per day (the threshold for absolute poverty) (Make Chocolate Fair 2013). In Ghana, the average daily income of cocoa farmers was USD 0.40–0.50 per day in 2017 (International Cocoa Initiative 2017). On average, farmers earn only 6.6% of the price at which the chocolate is sold in retail markets (Make Chocolate Fair 2013). The low prices and unpredictable markets trigger unsustainable production practices, such as the conversion of natural forests to plantations, with the intention of increasing revenues when prices are high; also, child labour exists in the sector (Make Chocolate Fair 2013).

The sustainable cocoa market is growing. In 2013, an estimated 2 million ha was being managed according to sustainability standards, "UTZ Certified" being the most important label. Cocoa certified as organic cocoa is increasingly popular in the United States of America and Europe, even though it represents only 0.5% of the world cocoa market (Badrie et al. 2015). Green and Black's, the leading producer of organic chocolate in the United Kingdom, increased turnover by 69% in 2004, compared with 2% in the rest of the industry (Badrie et al. 2015). Globally, the Dominican Republic dominates the market for organic cocoa, accounting for 70% of the market volume (Future Market Insights undated).

The cooperative serving Bolivia's Tacana indigenous people sells its cocoa beans for USD 4.4 per kg. The annual harvest averages 92–230 kg per year. Ninety percent of the harvest is sold, generating an income of USD 221–552 per family per year (the other 10% is consumed at home) (Anonymous 2018). The sale price obtained by farmers in Purus, Brazil, is reportedly lower than that achieved by the Tacana cooperative, at BRL 1.4 (USD 0.5) per kg in 2014 (Dantas and Quental 2014).

Choba Choba, a Swiss chocolate brand, is pursuing an innovative approach to produce chocolate using (among others) native cocoa from the Alto Huayambamba valley, Peru (Choba Choba undated).

16 Original Beans has a slogan, "one bar, one tree", in which it commits to planting and protecting one cocoa tree in the tropics per chocolate bar sold, including in the Beni region, where wild cocoa trees have been replanted (Original Beans undated).

The 40 participating cocoa farming families are shareholders of the brand, holding 30% of the shares of the company in 2020, with the plan to eventually own the majority (Choba Choba undated). The families participate in the company's decision-making process in various forms, such as in the price-setting mechanism for the cocoa they sell to their own company.

Conclusions

- Cocoa solids and cocoa butter are the main ingredients of chocolate, which has become immensely popular worldwide in the last 100 years. More than 4.5 million tonnes of cocoa beans is traded annually, and demand is increasing by 3% per year.
- The three most important diseases affecting cocoa are witch's broom, blackpod and frosty pod, which are all fungal infections of the bean pods or other parts of the tree and often lead to the loss of a significant part of the harvest.
- Various approaches for the prevention and treatment of the diseases exist. Quarantine measures are designed to prevent the spread of disease to unaffected areas; breeding aims to favour varieties with less susceptibility to disease; and integrated management and chemical and biological treatments aim to control the pathogens. Various studies have shown that these approaches can be effective, but further research is warranted.
- Re-agroforestation is being attempted in degraded areas in Brazil involving cocoa cultivation. In Bahia, cocoa is traditionally cultivated in agroforestry systems called *cabrucas* involving a canopy of native forest trees. Located near to natural forests, these shady plantations have a higher richness in bat species than observed in natural forests and could serve as biological corridors.
- Several examples exist in Bolivia and Brazil of successful wild-harvesting of cocoa. In most cases, niche markets could be developed in collaboration with producers of high-quality chocolate.
- Ninety percent of cocoa production globally comes from small-scale farmers, who often earn less than USD 1.25 per day, the threshold of absolute poverty. In Ghana, the average daily income of cocoa farmers was USD 0.40–0.50 in 2017. Even though the market for certified sustainable cocoa is growing, it still represents a small share of the total world market. In the case of wild harvesting, the cooperative of the Tacana indigenous people in Bolivia, which harvests cocoa in the wild, can sell its cocoa beans for USD 4.4 per kg.
- Little experience exists in introducing shade-tolerant varieties of cocoa to tropical timber production forests, but there is clear potential for co-management. There is interest in integrating wild cocoa in multiple-use management, such as through enrichment planting with wild cocoa in timber production forests. In the Brazilian Amazon, PWA is proposing to take a pioneering role in the management of forest plots enriched with wild cocoa.

4 SUSTAINABLE HARVESTING POTENTIAL OF PROMISING NON-TIMBER FOREST PRODUCTS

Combining the sustainable production of timber and NTFPs has various degrees of potential, depending on the context. Here we use a 1–5 star rating system to estimate the potential of various NTFPs (including those described in the case studies presented previously) to yield positive economic, social and environmental outcomes.

Note that some of the data presented in this chapter, especially on production volumes and prices, are quite old; there is an urgent need for new market studies of the NTFPs presented here, and others, to assist efforts to encourage sustainable production and thereby better contribute to forest conservation and the livelihoods of forest-dependent people.

★☆☆☆☆
No potential for sustainable harvesting, with various factors indicating likely negative outcomes

★★☆☆☆
Low potential for sustainable harvesting, with 1–2 significant factors indicating likely negative outcomes

★★★☆☆
Some potential for sustainable harvesting, but considerable challenges exist and negative outcomes are possible

★★★★☆
High potential for sustainable harvesting, with only minor negative factors

★★★★★
Extraordinary potential for sustainable harvesting with no or negligible negative factors

Species	Region/ ecological type	Uses	Ecological potential for wild harvesting	Social/cultural potential for wild harvesting	Economic potential for wild harvesting	Overall rating	References
Açaí (*Euterpe oleracea*)	Amazon Basin	Açaí juice and edible palm heart	★★★★☆ High abundance of palms, which are easily accessible to local people in margins of rivers Possibility of harvesting two NTFPs from the same tree Potential for the co-management of açaí fruit and timber because palms are abundant in logged areas Tendency for natural forests to transition into açaí plantations with considerable loss of biodiversity	★★★★★ Very important in local diets, with well-developed local markets Cooperatives and communities sustainably harvest and further process the fruit	★★★★★ In addition to local markets, there are growing regional, national and international markets Revenue from the marketing of açaí is substantially higher than for other NTFPs	★★★★★	Alves and Ramos (2019) Brondízio et al. (2002) Fortini and Carter (2014) Lopes et al. (2019) Menezes et al. (2011) Weinstein and Moegenburg (2004)
Achiote, urucum (*Bixa orellana*)	Amazon Basin; Central America	Natural colourant for foods and various industries (textiles, cosmetics, medicinal); extracted from seeds	★★★★☆ Fast-growing tree with first harvesting after 1.5 years Has been domesticated by local people for hundreds of years. Today, harvesting occurs from cultivated and uncultivated stands	★★★★☆ Important in the diet and traditions of local indigenous cultures. The dye, for example, is used as a body paint Local knowledge about the species is disappearing among younger generations	★★★★☆ Local and international markets are well-developed. Annual production volume worldwide is estimated at 17 500 tonnes, with 68% originating in the northeast of Brazil Trade prices are in the range of USD 800–1000 per tonne of seeds Increasing demand for natural dyes due to restrictions on the use of artificial dyes	★★★★☆	Ambrósio Moreira et al. (2015) Jansen (2005) Raddatz-Mota et al. (2017) Vedavathy (2003)
African cherry (*Prunus africana*)	Congo Basin	Bark used in the production of various medicines, especially in the treatment of benign prostatic hypertrophy	★☆☆☆☆ Most of the bark is collected in the wild The harvesting of bark is destructive because of the large amount of bark collected and the short harvesting rotation (often 5 years rather than the recommended 7–8 years) Due to large-scale commercialization and unsustainable harvesting, the resource has been widely overexploited	★★★★★ Widely used as a traditional medicine in Africa African cherry is one of the four most popular medicinal plants in West Africa	★★★☆☆ 1 kg of bark sells for USD 6 in Europe, but harvesters receive only USD 0.33 per kg Most of the profit of *P. Africana* is gained by a few elite exporters In 2007, the European Union imposed an import ban on the bark of African cherry, which would have allowed natural stocks to recover; the ban was overturned in 2011, however, after intensive lobbying There is no separate traceable supply chain for bark obtained from cultivated stands, so harvesters are taxed as for wild-harvested bark	★★★☆☆	Cunningham et al. (2016) Moss (2015) Nsawir and Ingram (2007)

Species	Region/ ecological type	Uses	Ecological potential for wild harvesting	Social/cultural potential for wild harvesting	Economic potential for wild harvesting	Overall rating	References
African plum (*Dacryodes edulis*)	Congo Basin	Edible fruit and seed	★★☆☆☆ Low density in natural habitat Only 5% of the fruit is harvested in the wild; the remaining share is collected from homegardens and plantations In contrast, the closely related fruit of *Dacryodes buettneri* is still collected from the forest in Gabon	★★★★★ Among the most consumed fruits in Central and West Africa Important source of food during the "hungry season" when cocoyam and rice are not yet ripe	★★★★☆ Well-developed regional and international markets Local farmers harvest 72–619 kg per year worth USD 9–160 So far, the further processing of the fruit, for example into oils, remains rare	★★★☆☆	Awono et al.(2002) Ayuk et al. (1999a) Falconer (1990) Iponga et al. (2017) Sunderland and Ndoye (2004) Verheij (2002)
Agarwood (*Aquilaria* and *Gyrinops* species)	South and Southeast Asia	Incense, perfume and medical purposes	★★★☆☆ Traditionally, harvesting is destructive by cutting open the trunk to remove the agarwood Due to overharvesting, trees in the wild are rare Traditional non-destructive practices by the Penan people seem to be sustainable Various techniques exist for the fast development of agarwood in plantations that could cover increasing demand and prevent overharvesting in the wild	★★★★★ Traditionally important in several cultures (Islamic, Buddhist and Hindu traditions) as an incense and for perfumes	★★★★★ Worldwide, the market is growing quickly, with only 40% of demand covered World's most valuable NTFP, with prices up to USD 250 per g Highly profitable activity for local people, with annual income up to USD 435; 13% of retail price is earned by local harvesters	★★★★☆	Akter et al. (2013) Blanchette et al. (2015) Donovan and Puri (2004) Jensen (2009) Kanazawa (2016) Liu et al. (2013) Plantations International (undated) Sampson and Page (2018) Soehartono and Newton (2001) ITTO (see www.itto.int/cites_ programme)
Aguaje, buriti, moriche (*Mauritia flexuosa*)	Amazon Basin	Edible fruit and juice, cosmetics industry	★★★☆☆ High abundance of palms, which inhabit wet zones and form clusters (aguajales, buritizal) Sustainable practices vary between communities and depend on the availability of necessary climbing equipment Destructive harvesting of fruit (when harvesters cut the palm to collect fruit) leads to a low density of adult female population	★★★★★ Highly important in local diets, with well-developed local markets Regional projects promote conservation and sustainable collection in communities Considered as a substitute for açaí during its off-season; in Brazil, açaí harvesters collect buriti during the inter-harvest season	★★★★☆ Important regional market. In Iquitos, Peru, it is estimated that more than 1 million fruits are consumed a day Buriti is used in the development of cosmetics products such as sunscreens In Peru, USD 0.5–1.2 per kg is paid in local markets, whereas in Brazil and Colombia the market prices ranged between USD 0.1–0.5, which is low compared to the value of other NTFPs. In Peru, it has been shown that aguaje contributes 15% of the annual income of a community; in Abaetetuba, Brazil, 60% of interviewees confirmed that they sell *M. flexuosa*	★★★★☆	Horn et al. (2018) Sousa et al. (2018) Virapongse et al. (2017)

Species	Region/ ecological type	Uses	Ecological potential for wild harvesting	Social/cultural potential for wild harvesting	Economic potential for wild harvesting	Overall rating	References
Allanblackia (*Allanblackia* species)	West Africa, Congo Basin	Edible oil	★★★★☆ Allanblackia trees are present in logged areas at densities of up to 15 trees per ha, which provides opportunity for co-management Wild harvesting plays a complementary but still significant role to domestication In the Novella project, detailed guidelines for sustainable harvesting are implemented	★★★☆☆ Well known among local farmers. Is one of several products produced by 75% of local people; they harvest and sell it for supplementary income Due to low prices, there is often no motivation among local people to harvest the product outside their farmlands	★★★☆☆ Establishment of Novella project and international product with Unilever, which provides fixed demand and price Undeveloped local markets with low prices and average annual income of USD 6–12 (considerably lower than for other forest products)	★★★☆☆	Amanor et al. (2003) Amanor (2006) Ofori et al. (2013) Samuel (2014)
Andiroba (*Carapa guianensis*)	Amazon Basin	Medicinal oils extracted from seeds	★★★★★ Medium to high abundance, with tree densities around 25 adult trees per ha; seedling densities of up to 150 per ha have been found in the Amazon Combined harvesting of timber and seeds is possible, which is promising because the timber and NTFP are both valuable products	★★★★☆ Locally used as a traditional medicine—Amazonia's most widely used natural remedy Knowledge on how to extract the oil, or the availability of a mechanical press, is necessary to process the seeds	★★★★★ Productivity ranges in the literature from 0.2 to 80.2 kg of seeds per tree per year It has been shown that productivity is higher in non-inundated forests than in inundated forests In addition to local markets, growing subnational, national and international markets are developing Profitable commercialization for local communities, comparable with Brazil nut and açaí. A community cooperative in Acre, Brazil, received USD 14 per kg for the seed oil (1 kg of seeds yields 0.45 kg of oil)	★★★★★	Klimas et al. (2012) Londres et al. (2017)
Aralu bulu (*Terminalia chebula, T. bellirica*)	Southeast Asia	Medicinal fruit	★★★☆☆ Medium abundance in the wild; a study in India observed about 36–112 plants per ha Traditional collection of fruit with a maximum of 70% of the trees harvested allows regeneration in the wild and is considered sustainable. However, high local demand for fruit and the destructive manner of harvesting with the pollarding of branches led to overexploitation and decline of the species in the wild in India The fruit is commonly harvested in September/October when the fruit is still immature. This leads to the removal of seeds from the forest	★★★★★ The fruit has been used traditionally for millennia to treat stomach disorders and in several Ayurvedic preparations In recent decades, it has been harvested and widely commercialized for the pharmaceuticals industry (herbal products) and the leather industry, where it is used due to its richness in tannin for the colouring of leather	★★★★★ Well-developed local markets, with an annual demand of 100 tonnes Trees begin bearing fruit after four years and continue to do so for 30–40 years, with an annual yield per tree of about 10 kg Prices in 2010 were found to be in the range of INR 100–200 (USD 2.5–5.00) per kg; in India, in cultivated stands of 100 plants, the average annual income from *T. chebula* in 2017 was estimated at about INR 28 000 (USD 440)	★★★★☆	Guleria et al. (2017) Pandey and Bhargava (2014) Jansen (2005a) Singh and Sharma (2010) Varghese et al. (2015)

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Babassu (*Attalea speciosa*)	Amazon Basin mainly	Oil, biofuel, fruit, flour, medicine	★★★★☆ High abundance of babassu palms in open spaces and in higher riverbank forests that are easily accessible to communities Multiple-use harvesting once trees reach fructification (6–8 years); productive for up to 40 years In the main ecological zone (northeastern Amazon), the harvest is mainly in the wild and mainly by women (*quebradeiras*) Potential for co-management with açaí fruit and timber because the palms are abundant in logged areas Not yet commercially planted, but recognized	★★★★☆ Important in local diets in certain Amazon states, with well-developed local markets, and there is potential for expansion into international markets Cooperatives and communities sustainably harvest and further process the fruit	★★★☆☆ Growing regional, national and international markets Revenue from the commercialization of babassu has been studied and is considered important	★★★★☆	Hill (2015) May et al. (1985) Miyasaka and Neto (2014) National Academy of Sciences (1975)
Brazil nut (*Berthollетia excelsa*)	Amazon Basin	Edible nuts; the nut oil is used in cosmetics	★★★★★ Abundant tree in the wild, with densities exceeding 26 trees per ha; non-destructive harvesting of the nuts The only globally traded seed that is entirely harvested in the wild in Amazon forest Existing approaches for the co-management of nut collection with timber harvesting or tourism have been demonstrated to be successful	★★★★★ Important in traditions and in the diets of local communities	★★★★☆ The world's most important NTFP by value, with exports exceeding 35 million tonnes in 2012 by Bolivia, Brazil and Peru Tens of thousands of rural households are involved in the collection of Brazil nut In Bolivia, well-established cooperatives and processing plants enable sales without middlemen In Brazil, a lack of processing industries and infrastructure for storage and transportation led to a production decline	★★★★★	Cronkleton et al. (2012) Guariguata et al. (2017) Rockwell et al. (2015) Zuidema (2003)
Cajuput oil, gelam (*Melaleuca cajuputi*)	Southeast Asia and Oceania	Leaves are processed to produce essential oils, which are used in the treatment of rheumatic disorders and colics	★★★★☆ One of the few species that grows in burnt peatland areas and acidic and saline soils Grows dominantly and does not allow other species, including local species, to establish In Indonesia, most of the *Melaleuca* is harvested in the wild in degraded areas; branches are cut and the leaves then further processed	★★★★★ Traditional medicinal oil in various countries in Southeast Asia	★★★★☆ Worldwide production of cajuput oil is difficult to estimate but may be more than 600 tonnes per year; Indonesia and Viet Nam are the main producers Farm-gate prices in 1997 were USD 7.2 per kg for lower-quality oil (20–55% cineole content) and USD 8.8–9.6 per kg for high-quality oil (55–65% cineole content) Oils are exported mainly to Europe	★★★★☆	Doran (2016) Giesen (2015) Nuyim (undated) Southwell and Lowe (1999)

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Chicle (*Manilkara zapota*)	Amazon Basin, Mexico and Central America	Edible fruit; the sap (latex) is used in the production of chewing gum	★★★☆☆ Trees are abundant in the wild, with up to 50 trees per ha Well-established sustainable forest management in Central America for more than 90 years in the Maya Biosphere Reserve Trees can be tapped for chicle only when they are mature at about eight years; most chicle production today derives from plantations in India	★★★★☆ Fruit is highly popular in Latin America Chicle tapping is labour-intensive and is used only rarely today for chewing-gum production	★★★☆☆ Has been widely replaced by petroleum-based synthetic gum; with growing interest in natural products, however, the market for chicle might increase again Local market for chicle fruit is well-developed, whereas the introduction of the fruit to the European market was unsuccessful	★★★☆☆	Brokaw et al. (1998) Mickelbart (1996) Rainforest Alliance (2012) Reyes-Gómez et al. (2018)
Cocoa (*Theobroma cacao*)	Amazon Basin	Chocolate production	★★★☆☆ • Re-agroforestation systems involving cocoa can help restore degraded forest areas and biological corridors • Wild cocoa management is feasible in production forests and encourages the maintenance of forests by local people • There is a risk of conversion of African tropical forests into plantations for the production of commercial cocoa	★★★★★ Large demand for chocolate, with an annual growth in consumption of 3% worldwide	★★★★☆ Niche markets exist for high-quality products, with increasing markets in developed countries Wild-harvested cocoa provides higher incomes for producers Enrichment of wild cocoa in managed forests in the Amazon has potential Most cocoa comes from plantations in West Africa; could be enriched as an understorey tree in managed forests	★★★★☆	Badrie et al. (2015) Original Beans (undated) Ruf et al. (2015) Schroth et al. (2016) Wickramasuriya and Dunwell (2017)
Damar (*Hopea* and *Shorea* species)	South and Southeast Asia	Resin used for caulking boats, incense, paints and varnishes	★★★☆☆ Low abundance in natural forests, with densities of 0.07–0.3 trees per ha, which has led to the widespread development of agroforestry systems Damar gardens present structural similarities to natural forests, with dense upper canopies and many birds and monkeys Various studies have indicated a tendency to convert damar forests to crop plantations	★★★★★ Local communities have a long tradition of collecting damar, with some damar gardens existing for more than 100 years	★★★★☆ The commercialization of damar resin generates similar net returns to other local crops Locals harvest up to 48 kg of resin per tree per year and tap about 20 kg of resin per day. Local selling prices range from USD 0.14 per kg in the Lao People's Democratic Republic to USD 0.42 per kg in Indonesia The market is considered stable, with growing subsectors, for example the use of natural additives in the food industry	★★★★☆	Appanah and Turnbull (1998) De Foresta (2017) Kusters et al. (2008)

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Essouk (*Garcinia lucida*)	Congo Basin	Medicinal use of bark and seeds	★★★☆☆ Usually occurs in high densities of greater than 150 plants/ha in the wild. In some regions in Cameroon, however, it is already considered threatened due to destructive harvesting Unsustainable harvesting of bark, especially when the whole circumference of the stem is harvested at once, leads to high mortality rates Domestication of the species is difficult because it grows in a specific environment on the slopes of hills and along or near streams	★★★★★ The bark of *G. lucida* is one of the most valued NTFPs in Cameroon, Equatorial Guinea and Gabon; it is used traditionally as a medicine to treat stomach and gynaecological disorders The bark and seeds can be used as an additive in the production of a fermented palm wine called odontol	★★★★☆ In Cameroon, *G. lucida* is usually harvested for household use. Nevertheless, local, national and international markets exist. About 33.7 tonnes of bark was exported in 2007, at a total value of USD 171 175 In a study in Cameroon in 2015, it was estimated that, at town markets, a basket of fruit costs about XOF 5000 (= USD 8.5), and a 25 kg bag of bark sold for XOF 15 000–20 000 (USD 25.5–51) At the local level, harvesters receive XOF 100–150 (USD 0.2–0.3) per kg of bark	★★★★☆	Guedje et al. (2007) Ingram and Shure (2010) Makueti et al. (2015)
Gutta-percha (*Palaquium* species)	Southeast Asia	The latex is used mainly in dentistry as a filling material	★★☆☆☆ The collection method in the nineteenth century was destructive because trees were felled and the latex collected. This harvesting procedure led to local extinctions of the species Today, the resin is tapped mainly from living trees, although yields are much lower. In 1920, 450 kg could be harvested per ha; today, the volume is 20 kg per ha annually	★★★☆☆ Important for centuries for indigenous peoples in the production of tools. The cultural importance is lower today	★★☆☆☆ Demand was very high in the nineteenth century, with more than 3.5 million kg imported annually by the United Kingdom. Today it is largely substituted by synthetic materials, although it is still used in dentistry as a natural plastic Other South American and African tropical species produce similar latex	★★☆☆☆	Plants for a Future (undated) Wong (2016)
Kitul palm, toddy (*Caryota urens*)	Asia	Sweet sap is obtained from the raceme of young flowers; starch is extracted from the stem	★★★★☆ Palms are abundant across tropical Asia, with densities of 700–1000 trees per ha The tree reaches maturity and produces flowers after 10–20 years. It grows best in large openings, with low growth in the understorey and overall a high susceptibility to disease For tapping, incisions are made in the sides of the flowers and ingredients such as pepper, salt or garlic are applied to stimulate the flow of sap The harvesting of palm heart from the kitul palm for the production of starch and kitul flour is destructive	★★★★☆ Various traditional drinks (*neera*) and dishes (*pannie*) are made from the syrup and sap The process of tapping the sap from the flower is a skilled job that requires experience because the flow of the sap has to be stimulated and at the same time the extension of the flower controlled	★★★★★ Sugar from the sap is high-quality, and it has well-developed national markets and international market potential (Australia) as a substitute for maple syrup Average yield is 7.5–11 litres of sap per day. The sap is boiled down to a syrup (6–8 litres of sap = 1 litre of syrup). On average, 243–324 litres of syrup are yielded per palm per year. 1 litre of syrup was sold for INR 53.3 (USD 5) in Sri Lanka in 2015; given that most homegardens in Sri Lanka have multiple palms (on average, one mature palm tree per year and household), the production of palm syrup has significant value for households	★★★★☆	Ashton et al. (2014) Everett (1995) Gunatilake et al. (1993) Wijewardena (2015)

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Kola nuts (*Cola* species, *nitida*)	Congo Basin	Edible and medicinal nuts	★★★★☆ In Nigeria, 70% of kola nuts are still harvested in the wild Kola nuts are harvested twice per year by collecting the fruit from the ground or using poles In general, the collection of kola fruit is sustainable. However, overharvesting (with only the "inferior" fruit left for regeneration) and the concomitant unsustainable bark harvesting can damage the trees	★★★★★ Important in local traditions and ceremonies In West Africa, locals offer the nuts to visitors as a gesture of hospitality	★★★★☆ Well-established market in West Africa, Côte d'Ivoire being the world's leading producer. Kola nuts are the most commercially valuable NTFP in Cameroon, with up to 50 tonnes sold annually at a value of USD 660 000 Markets are still mostly informal, with a lack of processing industries and infrastructure for storage Local nut collectors sell seeds for USD 1 per kg, and end-consumer prices can reach up to USD 15 per kg A major pest is the kola weevil, which can lead to the loss of 50–70% of the production	★★★★☆	Facheux et al. (2006) Ingram et al. (2012) Ma'ourová et al. (2019) N'Guessan et al. (2019) Tachie-Obeng and Brown (undated)
Manketti, essessang, okhuen (*Ricinodendron heudelotii*)	Congo Basin	Seeds are used as a thickening agent	★★★★★ Long-lived pioneer tree species, which is abundant in transition forests and abandoned farmlands *R. heudelotii* increases the fertility of soil and provides shade for important crops such as coffee and cocoa, although it prefers full-sun conditions at the sapling stage	★★★★☆ Considered by the locals as an important NTFP for generating additional income and as an essential food item for local households. Seeds are harvested, boiled and dried and used as a spice. In a study in Cameroon, at least 70% of households in villages were involved in the collection of *R. heudelotii* Product collection and processing are labour-intensive but require no investments or technical knowledge	★★★★☆ Local markets are well developed On average, *R. heudelotii* contributes 5–10% of total household cash income in Cameroon's humid forest zone. In some areas closer to urban zones, the seeds contribute 10–25% Average local prices in Cameroon in 2010 were USD 2.48 per kg; the traded quantity per household was 20–40 kg per year, depending on the region in Cameroon. Most households earned USD 30–110 per year, with some earning up to USD 860	★★★★☆	Cosyns et al. (2011) Ndoye et al. (1998) Norgrove et al. (2002) Vivien and Fauré (1996)
Peru balsam (*Myroxylon balsamum var. Pereirae*)	Amazon Basin and Central America	Used for flavouring foods and in perfumes and medicaments. The edible nut and nut oil are used in the production of cosmetics	★★★★☆ Harvesting takes place when the tree is 20–30 years old by cutting wounds in the bark to stimulate resin production Harvesting of Peru balsam occurs mainly in the wild, although abundance and production are limited (only 3 kg of resin is collected per tree a year) Sustainable harvesting practices have been implemented for more than 100 years in El Salvador	★★★★★ Locally used as a traditional medicine Well-organized cooperatives exist in El Salvador; traditional techniques are still required to extract the oil	★★★★☆ There is a well-established European market. The balsam is sold mainly from El Salvador for a good price (EUR 13.48 per kg in 2008) FairWild certification ensures stable prices and sustainable production Can be replaced by synthetic balsam	★★★★☆	FairWild (2019) Orwa et al. (2010) Michiels (2015)

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Rattan (*Calamus* and *Daemonorops* species)	South and Southeast Asia	Stems are used in the production of furniture and baskets and in the construction sector	★★★★☆ Almost entirely harvested in natural forests and homegardens Overall tree density and species diversity have been observed to be maintained in areas with rattan harvesting Economic boom led to overharvesting in the 1970s	★★★☆☆ Widely used for various products Harvesting is especially important for men who are unable to engage in rice or cash crop farming Due to the labour-intensive work and low prices, many farmers prefer to invest in more profitable palm oil or rubber	★★★☆☆ International markets are well developed, with processed products to the value of USD 892 million traded worldwide Export bans led to an oversupply of rattan and significant price drops. The price was USD 0.69 per kg in the 1980s but only USD 0.15 per kg in 2010	★★★☆☆	Meijaard et al. (2014) Siebert (2000) Sunderland (2000)
Rubber (*Hevea brasilienis*)	Amazon Basin	Various industrial uses for the latex, for example in the tyre and medical industries	★★☆☆☆ Asian rubber plantations are mainly monocultures on land previously converted from natural forest In Brazil, well- established production chains are publicly subsidized with the aim of preventing the expansion of cattle ranching Nevertheless, only about 1% of processed rubber globally is from native forests, deriving from a cooperative in Pará	★★★★★ Rubber-tapping is a well-recognized activity in the Brazilian Amazon, and there is a strong pro-rubber-tapping movement Rubber-tapping is skilled and labour-intensive	★★★☆☆ High worldwide demand. However, 60% of rubber is produced synthetically today, with most of the rest produced in plantations The harvest per person in natural forests is more than 30 times lower than in plantation. A rubber tapper may harvest 500–600 kg year in natural forests and up to 20 tonnes per year in plantations Even though rubber-tapping is subsidized by the state in Brazil, it delivers lower annual income than cattle ranching (USD 1–8 per ha per year versus USD 50 per ha per year)	★★★☆☆	Campos (undated) Heng and Joo (2017) Jaramillo-Giraldo et al. (2017) Mercur (undated) Reis (2015)
Sago (*Metroxylon sagu*)	Southeast Asia	The pith of the stem is rich in starch and used to make sago. The fruit is also edible	★★★☆☆ Sago palms are dominant and grow in the wild in flooded areas in groups. It is estimated that sago palms cover more than 6 million ha in Indonesia The starch can be harvested when the palm reaches eight years of age. The stem must be cut open to collect the starch, so the harvesting is destructive A single palm yields 150–300 kg of sago	★★★★★ Sago has been used as a staple food for a long time in Southeast Asia and is still important in local diets and the preparation of traditional dishes	★★★★★ Large-scale commercialization can provide a rate of return on investment of more than 10%. Moreover, the labour required for the production of 1 kg of starch is lower than for any other type of starch The market is well-developed and growing in Indonesia The main international market is Japan, which imports an average of 20 000 tonnes annually Cassava starch is more abundantly available and easier to process. There is a growing market for sago, however, for example in the production of biodegradable plastic	★★★★☆	Fern (2019) Flach (1997) Lal (2003)

Species	Region/ ecological type	Uses	Ecological potential for wild harvesting	Social/cultural potential for wild harvesting	Economic potential for wild harvesting	Overall rating	References
Sandalwood (*Santalum* spp.)	South and Southeast Asia	The oil is used in perfumes and cosmetics	★☆☆☆☆ Plants in the wild are rare due to overharvesting The harvesting is destructive, with the oil extracted from the heartwood of stems, branches and roots Oil recovery is low, at 2.6%. Only 26 g of sandalwood oil is extracted from 1 kg wood, which is considerably less than (for example) the recovery rates of turpentine and gum resin oil Most sandalwood today is sourced from plantations in India and Australia	★★★☆☆ Locally used in ceremonies and as a traditional medicine In Indonesia, the government implemented strict regulations for harvesting in 1998, which led to a significant decline in the importance of sandalwood for the local people	★★★★☆ The demand for sandalwood is stable and high. The oil is mainly exported to Europe, Singapore and the United States of America Trade prices for sandalwood oil are in the range of USD 71–160 per kg	★★★☆☆	CIFOR (2004) FAO (1995) Lim (2019)
Wild spinach (*Gnetum africanum*)	Congo Basin	Leaves are consumed as a vegetable	★★★☆☆ Abundant in forests and other habitats (e.g. savanna, fallows and abandoned farmlands) Local people usually cut down trees on which *Gnetum* vines grow, which leads to the death of the trees The roots are also a source of food. Intensive vine harvesting by local people often causes damage to the roots and makes them susceptible to fungi infection	★★★★★ Traditional part of local diets Highly important in droughts as a source of food for local tribes because the leaves can be collected year-round	★★★★☆ Well-developed local and international market, with > 44 000 tonnes sold in 1997 The trade provides many well-paid jobs, with monthly salaries up to USD 750 per month	★★★★☆	Ali et al. (2011) Ingram et al. (2012) Tekwe et al. (2003)
Wild mango (*Irvingia gabonensis*)	Congo Basin	Edible fruit and kernel (nut)	★★★★☆ Abundant tree in West and Central Africa (an average of 1.9 stems per ha were counted in Cameroon); the fruit is still mainly collected in the wild Deforestation has reduced the availability of the forest resource Enrichment planting must be developed because demand for the fruit is high and in some cases the resource is overharvested	★★★★★ One of the most consumed fruits in Central and West Africa The kernel is highly appreciated by local people and used in the preparation of traditional dishes The collection of two important food sources from the tree (fruit and nuts) provides food security in the region	★★★★★ Significant trading volumes in West Africa. It is estimated that 12 million tonnes of kernel are sold annually in Nigeria. The main producers are Cameroon, Côte d'Ivoire and Nigeria In 1994, the average annual income per collector from the sale of wild mango fruit and kernels in Cameroon was estimated at USD 78	★★★★★	Ayuk et al. (1999b) Ladipo (2000) Ngansop et al. (2019)

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Xaté (*Chamaedorea* spp.)	Central America	Leaves for construction and handcrafts	★★★☆☆ The palm occurs in high abundance in forest understoreys, with densities reaching 5000 stems per ha or more; it is found in a wide range of forest types, including in the Mayas Mountain Range up to 1100 m above sea level The leaves of at least seven species from the genus *Chamaedorea* have an established international market, with most of the leaves still collected from forests In a study in Mexico, *C. radicalis* was found to be quite resilient to harvesting, mainly due to its high abundance and because harvesting is restricted to adult palms. Nevertheless, 75% of *Chamaedora* species are listed as threatened, and illegal harvesting is a serious problem in protected areas such as the Chiquibul Forest Reserve in Belize	★★★★★ The collection of leaves from *Chamaedorea* species is a widespread activity; a market has existed since the 1940s, and thousands of communities in Mexico and Guatemala are engaged in this activity No expensive equipment or expert knowledge is needed for the harvesting of xaté —the leaves are simply cut by hand with small knives	★★★★★ There is a well-developed national and international market. In 1999, about 2000 tonnes of *Chamaedorea* were exported from Mexico, generating about USD 20 million. In the Maya Biosphere Reserve in Guatemala, the value of exports of xaté is comparable to the value of timber harvest in the region Harvesters collect 1000–1500 leaves on a good day. In 2006, the average value of 100 leaves paid to *xateros* (collectors of xaté leaves) varied between USD 0.30 and USD 1.70, which corresponds to a daily income of USD 3–17 (the minimum legal wage in Guatemala USD 5)	★★★★☆	Bridgewater et al. (2006) Endress et al. (2006) Millner et al. (2020)

5 LOOKING FORWARD: TOWARDS MULTIPLE-USE MANAGEMENT FOR TIMBER AND NON-TIMBER FOREST PRODUCTS

The management of natural tropical forests for the sole purpose of harvesting timber is an archaic practice that has proved to be a sustainable land-use option in only exceptional cases. Given the growing demands on tropical forests, effective multiple-use management systems are needed that enable the sustainable provision of timber, NTFPs and ecosystem services. In the future, multiple-use forest management encompassing sustainable wood and NTFP production, conservation and the provision of ecosystem services, including carbon sinks, are the most likely means to satisfy economic, social and environmental goals.

This review has examined methods for retaining the management of timber as a primary output while integrating NTFPs as secondary outputs, implying a shift from a single focus on timber towards multiple-use management. For illustrative purposes, the review has focused on several broadly recognized and valuable NTFPs common in tropical moist forests, and it has also scrutinized some lesser-known NTFPs and evidence on the extent to which they could be integrated with timber production. Moreover, several hundred other species are already being used locally as NTFPs and could be further developed.

The review shows that the compatible management of timber and NTFPs is inherently multifactorial and context-dependent. Compatibility is possible in some cases but might prove difficult to achieve in others, at least in the short run. There is, however, a lack of studies on integrated management approaches that effectively combine the production of timber and NTFPs; the concept, therefore, requires field-level implementation to explore its feasibility.

Governance issues, such as those related to land tenure, collective institutions, and the design of multistakeholder management models, must be addressed to enable multiple-use forest management in the tropics. Testing pilot multiple-use management approaches in forests where governments have a direct supporting role could prove fruitful. The Central African regional norms developed for managing NTFPs (FAO 2008) indicate how countries could incorporate NTFPs in policy, legal, fiscal and institutional frameworks and provide a working model.

There are three (interrelated) ways to move forward on multiple-use forest management involving timber and NTFPs, based on Guariguata et al. (2010):

1) indirectly improving "passive" or "opportunistic" compatibility situations, for example by enforcing the mitigation of logging impacts on NTFP resources;
2) explicitly enhancing both timber and NTFP values, including through the concurrent management of locally important NTFPs; and
3) assessing the biophysical (forest), social, regulatory and institutional aspects of multiple-use forest management for timber and NTFPs with a view to minimizing trade-offs among stakeholders.

For many NTFPs, recent information on production volumes and prices is lacking, including for some major NTFPs. There is an urgent need, therefore, for market studies of the NTFPs presented here, and others, to assist efforts to encourage sustainable production and thereby better contribute to forest conservation and the livelihoods of forest-dependent people. Coordinated marketing campaigns are also needed to establish sustainable markets for NTFPs, many of which remain niche products in domestic markets.

The practicalities and effectiveness of multiple-use forest management will depend on the scale of management, the intensity of harvesting for timber and NTFPs, the ecological overlap between timber and NTFP resources in a given forest, and the quality of harvesting (e.g. low-impact logging versus more destructive "conventional" logging). A range of potential scales exists, from large industrial timber concessions where NTFPs are integrated into commercial production systems, to local enterprises making use of timber and NTFPs in community forests. The technical norms for Brazil-nut management in Bolivia, as outlined in a 2005 state regulation, require forest owners to establish "no-take" zones of up to 6% of the total production area for up to five years. The norms provide little guidance on where in the forest these areas should be created or address the high light requirements needed for the establishment of Brazil-nut saplings (Cotta et al.

2008). The norms require detailed inventories of Brazil-nut trees and the measurement of commercial bole height and degree of crown illumination, even though there is no obvious connection with nut harvesting and management practices. In contrast, NTFP norms and regulations developed at the national level may disregard the possibility that timber harvesting may overlap with NTFP production. Although there are documented initiatives in Brazil to train tropical foresters in bridging the gap between timber and NTFP use, ecology and management (Guedes Pinto et al. 2008), little progress has apparently been made elsewhere in the tropics.

There is an estimated 403 million ha of natural production forest allocated to timber production in the permanent tropical forest estate worldwide (Blaser et al. 2011), and a similar area of natural tropical forest is accessible to or under the control of rural communities (Sunderlin et al. 2008). Considerable opportunities exist, therefore, for designing and validating integrated management approaches that include the use of timber and NTFPs in the same location; the valorization of ecosystem services such as carbon storage, water-flow regulation and biodiversity conservation through payment schemes for ecosystem services could also add value to multiple-use forest management. Integrating NTFP management in timber production forests could be a decisive step in the development of such management approaches, thus conserving tropical natural forests, bearing in mind the imperative to use these crucial natural resources wisely and sustainably, or lose them forever.

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Tropical forests contain much more value, commercially and for communities, than just timber. For centuries, forest-dependent peoples have known and used numerous edible nuts, fruits and other plant and animal products for food and medicine—what today we call non-timber forest products (NTFPs).

This report, which draws on the authors' field experience and a thorough review of the literature, explores multiple-use forest management approaches in which NTFPs help make the economic case for natural forests. It presents three examples of well-established NTFPs in humid tropical forests—Brazil nut, rattan and rubber. For each, it examines the factors and strategies that have enabled the sustainable harvesting of the NTFP, as well as the challenges in maintaining a sustainable NTFP management regime.

The report also describes six promising NTFPs that grow in tropical forests—two each from tropical Africa, Southeast Asia and the Amazon—for which the potential is yet to be fully realized. And it uses a five-star system to rate the potential of 28 individual NTFPs to yield positive economic, social and environmental outcomes.

The report concludes that integrating NTFP management in timber production forests could be a decisive step in ensuring economic viability, bearing in mind the imperative to use natural tropical forests wisely and sustainably, or risk losing them forever.

Precious Forests Foundation

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